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Knowledge for the People:

OR, THE PLAIN

WHY AND BECAUSE.

FAMILIARIZING SUBJECTS OF USEFUL CURIOSITY AND AMUSING RESEARCH.

BY JOHN TIMBS,

Editor of 'Laconics:' 'Arcana of Science and Art,' &c.

"Its beginning is pleasure, its progress knowledge, and its objects truth and utility."—*Sir Humphry Davy.*

Popular Chemistry—Mechanics—Arts and Manufactures.

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* *Erratum, at page* 46, *for* "torpedo, or electric eel," *read* "torpedo, or electric ray."

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KNOWLEDGE FOR THE PEOPLE:

OR THE

PLAIN WHY AND BECAUSE.

PART V.—POPULAR CHEMISTRY.

POPULAR CHEMISTRY.

INTRODUCTORY.

Why is the science of chemistry so named?

Because of its origin from the Arabic, in which language it signifies "the knowledge of the composition of bodies."

The following definitions of chemistry have been given by some of our best writers:—

"Chemistry is the study of the effects of heat and mixture, with the view of discovering their general and subordinate laws, and of improving the useful arts." —*Dr. Black.*

"Chemistry is that science which examines the constituent parts of bodies, with reference to their nature, proportions, and method of combination."—*Bergman.*

"Chemistry is that science which treats of those events or changes, in natural bodies, which are not accompanied by sensible motions."—*Dr. Thompson.*

"Chemistry is a science by which we become acquainted with the intimate and reciprocal action of all the bodies in nature upon each other."—*Fourcroy.*

The four preceding definitions are quoted by Mr. Parkes, in his *Chemical Catechism.*

Dr. Johnson (from Arbuthnot) defines "chemistry" as "philosophy by fire."

Mr. Brande says "It is the object of chemistry to investigate all changes in the constitution of matter, whether effected by heat, mixture, or other means."—*Manual*, 3rd edit. 1830.

Dr. Ure says "Chemistry may be defined the science which investigates the composition of material substances, and the permanent changes of constitution which their mutual actions produce."—*Dictionary*, edit. 1830.

Sir Humphry Davy, in his posthumous work,* says, "There is nothing more difficult than a good definition of chemistry; for it is scarcely possible to express, in a few words, the abstracted view of an infinite variety of facts. Dr. Black has defined chemistry to be that science which treats of the changes produced in bodies by motions of their ultimate particles or atoms: but this definition is hypothetical; for the ultimate particles or atoms are mere creations of the imagination. I will give you a definition which will have the merit of novelty, and which is probably general in its application. *Chemistry relates to those operations by which the intimate nature of bodies is changed, or by which they acquire new properties.* This definition will not only apply to the effects of mixture, but to the phenomena of electricity, and, in short, to all the changes which do not merely depend upon the motion or division of masses of matter."

Cuvier, in one of a series of lectures, delivered at Paris, in the Spring of last year, says "the name chemistry, itself, comes from the word *chim*, which was the ancient name of Egypt;" and he states that minerals were known to the Egyptians "not only by their external characters, but also by what we at the present day call their *chemical characters*." He also adds, that what was afterwards called the Egyptian science, the

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* Consolations in Travel; or the Last Days of a Philosopher. 1830

Hermetic art, the art of transmuting metals, was a mere reverie of the middle ages, utterly unknown to antiquity. "The pretended books of Hermes are evidently supposititious, and were written by the Greeks of the lower Empire."

Why is chemistry essential to man in his highest state of cultivation?

Because every part of his body is covered with the products of different chemical and mechanical arts; made not only useful in protecting him from the inclemency of the seasons, but combined in forms of beauty and variety; creating out of the dust of the earth, from the clay under his feet, instruments of use and ornament; extracting metals from the rude ore, and giving to them a hundred different shapes for a thousand different purposes; selecting and improving the vegetable productions with which he covers the earth; making the winds carry him on every part of the immense ocean; and compelling the elements of air, water, and even fire, as it were, to labour for him; concentrating in small space materials which act as the thunderbolt, and directing their energies so as to destroy at immense distances; blasting the rock, removing the mountain, carrying water from the valley to the hill, &c. Or, to be more minute, the rendering skins insoluble in water, by combining with them the astringent principle of certain vegetables, is a chemical invention; and without leather, our shoes, our carriages, our equipages, would be very ill made: the bleaching and dyeing of wool and silk, cotton and flax, are chemical processes, and the conversion of them into different clothes, is a mechanical invention; the working of iron, copper, tin, lead, and the other metals, and the combining them in different alloys, by which almost all the instruments necessary for the turner, the joiner, the stonemason, the shipbuilder, and the smith, are made, are chemical inventions; even *the press* could not have existed in any state of perfection without a metallic alloy. The combining of alkali and sand, and certain clays and flints together, to form glass and porcelain, is a chemical process;[*] the colours which the artist employs to frame resemblances of natural objects, or to create combinations more beautiful than ever existed in nature, are derived from chemistry;—in short, in every branch of the common and fine arts, in every department of human industry, the influence of this science is felt; and we may find in the fable of Prometheus taking the flame from heaven to animâte his man of clay, an emblem of the effects of fire, in its application to chemical purposes, in creating the activity and almost the life of civil society.—*Abridged from "the Last Days of a Philosopher," by the late Sir Humphry Davy.*

Why may real philosophers be considered to have done much by their own inventions for the useful arts?

Because the chemical or mechanical manufacturer has merely applied what the philosopher has made known; he has merely worked upon the materials furnished to him. Thus, the chlorine, or oxymuriatic gas, of Scheele, was scarcely known, before it was applied by Berthollet to bleaching; scarcely was muriatic gas discovered by Priestley, when Guyton de Morveau used it for destroying contagion. Platinum has owed its existence, as a useful metal, entirely to the labours of an illustrious chemical philosopher; look at the beautiful yellow afforded by one of the new metals, chrome; consider the medical effects of iodine, in some of the most painful and disgusting maladies belonging to human nature, as cancer and bronchocele. We have no history of the manner in which iron was rendered malleable; but we know that platinum could only have been worked by a person of the most refined chemical resources.—*Sir H. Davy.*

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[*] The improvements of porcelain in this country, as well as those made in Germany and France, have been entirely the result of chemical experiments; the Dresden and the Sèvres manufactories have been the work of men of science; and it was by multiplying his chemical researches, that Wedgewood was enabled to produce, at so cheap a rate, those beautiful imitations, which, while they surpass the ancient vases in solidity and perfection of material, equal them in the elegance, variety, and tasteful arrangement of their forms.

Why is the apparatus essential to the modern chemist much less bulky and expensive than that used by the ancients?

Because an air-pump, an electrical machine, a voltaic battery, (all upon a small scale) a blowpipe apparatus, a bellows and forge, a mercurial and water-gas apparatus, cups and basins of platinum and glass, and the common re-agents of chemistry, are all that are required. All the implements absolutely necessary, may be carried in a small trunk; and some of the best and most refined researches of modern chemists, have been made by an apparatus which might with ease be contained in a small travelling carriage, and the expense of which is only a few pounds. Chemistry is not injurious to the health; the modern chemist is not like the ancient one, who passed the greater part of his time exposed to the heat and smoke of a furnace, and the unwholesome vapours of acids and alkalies, and other menstrua, of which, for a single experiment, he consumed several pounds.—*Sir H. Davy.*

ATTRACTION OR AFFINITY.

Why is our earth a globe?

Because of the general attraction by which all its parts are drawn towards each other, that is, towards a common centre; by which means the mass assumes the spherical or rounded form.

We have interesting instances of roundness from the same cause in minute masses,—as the particles of a mist or fog floating in air,—there, mutually attracting and coalescing into larger drops, and then forming rain—dew-drops—water trickling on a duck's wing—the tear dropping from the cheek—drops of laudanum—globules of mercury, like pure silver beads, coalescing when near, and forming larger ones—melted lead allowed to rain down from an elevated sieve, which, by cooling as it descends, retains the form of its liquid drops, and becomes the spherical shot-lead of the sportsman.—*Arnott.*

Why is the prescription of medicine by drops an unsafe method?

Because, not only do drops of fluid from the same vessel, and often of the same fluid of different vessels, differ in size, but also drops of the same fluid, to the extent of a third, from different parts of the lip of the same vessel.

Why has it been said that the whole world, if the atoms could be brought into absolute contact, might be compressed into a nutshell?

Because of the exceedingly little of really solid matter even in the densest mass, as evident in the non-contact of atoms, even in the most solid parts of bodies; from the very great space obviously occupied by pores; the mass often having no more solidity than a heap of empty boxes, of which the apparently solid parts may still be as porous in a second degree, and so on; and from the great readiness with which light passes in all directions through dense bodies, like glass, rock crystal, diamond, &c. We have as yet no means of ascertaining exactly what relation this idea has to truth.—*Arnott.*

Why may the doctrine of ultimate atoms be considered as established?

Because, according to the late Dr. Wollaston, the earth's atmosphere is limited, and consequently matter has a finite divisibility. "Yet," observes another, "of the smallest atom we can always imagine the half."

Why is the density, or the quantity of atoms which exist in a given space, very different in different bodies?

Because of three different circumstances: first, of the size or weight of the individual atoms; secondly, on the degree of porosity just now explained; thirdly, on the proximity of the atoms in the more solid parts, which stand between the pores. As an example of the different degrees of density, a cubic inch of lead is 40 times heavier than the same bulk of cork.—*Arnott.*

Why are certain bodies solid?

Because their parts cohere so firmly as to resist impression.

Lavoisier has explained solidity thus:—"The particles of all bodies may be considered as subject to the action of two opposite powers, repulsion and attraction, between which they remain in equilibrio. So long as the attractive force remains stronger, the body must continue in a state of solidity; but if, on the contrary, heat has so far removed these particles from each other, as to place them beyond the sphere of attraction; they lose the cohesion which they before had with each other, and the body ceases to be solid."

Why do blue and yellow powders, when mixed, form a green powder?

Because of the mere effect arising in the eye from the intimate mixture of the yellow and blue light separately and independently, reflected from the minute particles of each; and the proof is had by examining the mixture with a microscope, when the yellow and blue grains will be seen separately and quite unaltered. —*J. F. W. Herschel.*

Why cannot a similar separation be detected in liquid green?

Because of the excessive minuteness of the parts, and their perfect intermixture, by agitating the blue and yellow liquids together. From the mixture of two powders, extreme patience would enable any one, by picking out with a magnifier grain after grain, to separate the ingredients. But when liquids are mixed, no mechanical separation is any longer practicable: the particles are all so minute as to elude all search. —*J. F. W. Herschel.*

Why do we use the term specific gravity to express the relative weight of bodies?

Because it denotes the weight of the matter of which any body is composed, compared with the weight of pure distilled water, at 60° Fahrenheit, assumed as a standard.

Why is there a difference in the specific gravity of different bodies?

Because one body is larger, or takes up more room than another of the same weight, when the first is said to be *specifically* lighter than the other, and *vice versâ*.

The specific gravity of bodies is denoted, in chemical writings, by comparing it with the specific gravity of pure water, in decimal figures, water being always considered as 1.000. Thus the *specific gravity* of the strongest sulphuric acid is 1.850, or nearly nine tenths heavier than water. Iron is 7.650, or more than 7½ times heavier than water; that is, a cubic inch of iron, if put into a scale, would require 7½ inches to balance it; silver is 10.478; gold, 19.300; and platinum, 23.000, or 23 times heavier than water. The specific gravity of all bodies is noted in the same way.—*Parkes.*

Why does some stone decay rapidly, although very hard when first dug from the quarry?

Because it abounds with clay, or alumine, which has so great an affinity for water as to absorb moisture from the atmosphere, and thus destroy itself.

Why will not oil and water mix in a vial upon being violently shaken?

Because the water and the oil have no *affinity* for each other; but if some caustic ammonia be added, and the vial then agitated, the whole will be mixed into an ammoniacal soap. This is what is called *disposing affinity,* or uniting bodies, which apparently have no tendency to unite of themselves, by the addition of another substance.

Why do small needles float on water?

Because the particles of water cohere among themselves, and the weight of the needles is not sufficient to overcome that cohesion.

Why do a pound of water, and a pound of salt when mixed, form two pounds of brine, but then occupy much less bulk than when separate?

Because the atoms of the one are partially received into what were vacant spaces in the other. A similar condensation is observed in many other mixtures; as a pound of sugar in a pound of water. Tin and copper, melted together to form bronze, occupy less space by one fifteenth, than they do when separate.—*Arnott.*

Why are a hundred pints of common air to be compressed into a pint vessel, as in the chamber of an airgun?

Because, in aeriform masses, the atoms are very distant, and hence the masses are more easily compressed. In this case, if the pressure be much further increased, the atoms will at last collapse, and form an oily liquid. The heat which was contained in such air, and gave it its form, is squeezed out in this operation, and becomes sensible all around.—*Arnott.*

Why are liquids said to be saturated?

Because they cannot combine with, or take up, more than a certain quantity of any solid or aëriform body; the point at which this action ceases is *saturation:* thus, water will only take up a certain known weight of alum, salt, &c.

Why is gravitation the first and most general cause of changes on the earth?

Because water, raised in vapour by the heat of the sun, is precipitated by the cool air in the atmosphere; it is carried down by gravitation to the surface; and gains its mechanical force by this law.— *Sir H. Davy.*

Why does the pyramid last longer than other forms?

Because it is most fitted to resist the force of gravitation.

Why is an apartment never literally empty?

Because, if it offer to view nothing but the naked walls, it is full of air, just as an open vessel, immersed in the sea, is full of water; and if air were not allowed to escape from it, even so small a body as an apple could not be pressed into it additionally by less force than fifty or sixty pounds.

Why is heat produced on slacking quick-lime?

Because of the violence of the chemical action, and the solidification of the water. In this process 68 parts of lime solidify 32 parts of water; but it is remarkable, that in making what we call lime-water, 500 parts of water are required to dissolve one part of lime.

Why is it a vulgar error to say quick-lime, or oil of vitriol, burns?

Because they powerfully corrode animal and vegetable substances, and become violently hot from their combination with water. "They are, therefore, set down in vulgar parlance, as substances of a hot nature; whereas, in their relations to the physical cause of heat, they agree with the generality of bodies similarly constituted." They owe the sensation of heat which they excite, to chemical stimulants, and not at all to their being actually hot.

Why are not bitter and sweet essential qualities of matter?

Because, as Dr. W. Herschel has recently discovered, the mixing of nitrate of silver with hypo-sulphate of soda, both remarkably bitter substances, produces the sweetest substance known. Thus, bitter and sweet, as well as sour, appear not to be an essential quality in the matter itself, but to depend on the proportions of the mixture which composes it.

CRYSTALLIZATION.

Why do the figures of crystals vary in regularity?

Because their regularity is influenced by the rapidity of the evaporation: thus, if the process be slowly conducted, the particles unite with great regularity;

if hurried, the crystals are irregular and confused. To obtain very regular crystals, the evaporation must be spontaneous, or that which takes place at common temperature.

Why is the Giant's causeway disposed in angular columns?

Because it is supposed that the whole body of the rock was once in a state of fluidity, being no other than the lava of a burning mountain; that the prodigious mass cracked in its cooling, into the above forms; that it may since in some measure have been deranged by earthquakes; that these have swallowed up the volcano itself; and that the waters of the neighbouring ocean now roll over the place where once it stood.—*Parkes.*

The most remarkable basalt is the columnar, which forms immense masses, composed of columns, thirty, forty, or more feet in height, and of enormous thickness. Those at Fairhead are 250 feet high. The coast of Antrim, in Ireland, for the space of three miles in length, exhibits a very magnificent variety of columnar cliffs; and the Giant's causeway consists of a point of that coast, formed of similar columns, and projecting into the sea for a descent of several hundred feet. These columns are for the most part hexagonal, (or six-sided) and fit very accurately together; but most frequently not adherent to each other, though water cannot penetrate between them. In the Hebrides are likewise some vast specimens of basalt.

Why are certain bodies porous, or full of small vacant spaces?

Because of the crossing of the constituent crystalline needles or plates in bodies.—*Arnott.*

Why are crystals mechanically divided only in certain directions, so as to afford smooth surfaces?

Because, in every crystallized substance, whatever may be the difference of the figure which may arise from modifying circumstances, there is, in all its crystals, a *primitive* form, the nucleus, as it were, of the crystal, invariable in each substance, giving rise to the actually outward existing forms.—*Parkes.*

Why has strong salt and water a pellicle (or film) on its surface?

Because the attraction of the saline particles for each other is becoming superior to their attraction for the water. This is the common criterion of the fitness of a solution for crystallization.

Sir Isaac Newton seems to have had a very clear idea of the cause of crystallization. "When," says he, "a liquor saturated with a salt, is evaporated to a pellicle, and sufficiently cooled, the salt forms in regular crystals Before being collected, the saline particles floated in the liquor, equally distant from each other; they acted, therefore, mutually on each other, with a force which was equal at equal distances, and unequal at unequal distances; so, in virtue of this force, they must arrange themselves in an uniform manner."—*Newton's Optics, Book* iii.

Why will not salt crystallize when dissolved in a considerable quantity of water?

Because the particles of the salt are too far asunder to exert reciprocal attraction: in other words, they are more powerfully attracted by the water, than by each other.—*Brande.*

Why does the salt crystallize upon evaporation of part of the water?

Because some of the saline particles then gradually approach each other, and they will, according to certain laws, become regular solids; another portion of the salt will remain dissolved in the water which is left; this is usually called the *mother liquor*, or water.

There is a great variety in the form of crystallized salts, and each salt preserves its own peculiar form thus, common culinary salt generally crystallizes in small tubes, and sulphate of soda in six-sided prisms.

Why do certain salts (called freezing mixtures) convert water into ice?

Because, as heat is required to convert solids into liquids, it follows, that in cases of sudden liquefaction, (as when the salts are dissolved in the water) *cold* will ensue: hence its production during the solution of many saline bodies, and hence, also, the explication of the theory of *freezing* mixtures

The artificial preparation of ice has occupied much of the attention of modern chemists. The most recent experiments were made by M. B. Meijlink, who, after numerous trials, with different salts, for the purpose of converting water contained in a tin vessel into ice, during their solution, ultimately gave the preference to a mixture of four ounces of nitrate of ammonia, four ounces of sub-carbonate of soda, and four ounces of water. This mixture, in three hours, produced ten ounces of ice; whilst, with the mixture of sulphate of soda and muriatic acid, he obtained ice only after seven hours. —*Brande's Journal*, 1829.

Why do many salts, when exposed to the air, effloresce, or fall to powder?

Because they lose their water of crystallization.

Why do some salts effloresce more than others?

Because some thus completely lose their water; while others retain different quantities, according to the dryness of the air.

Why do some salts deliquesce, (or become moist or liquid) by exposure to the atmosphere?

Because they attract water from the atmosphere.

Why are not salt boilers made of cast iron?

Because the cast iron would crack by the adhesion of the salt.

Why is salt-petre refined by solution in water?

Because the rough petre, as it is called, is always contaminated with muriate of soda and other salts. In order, therefore, to separate them, the refiners dissolve the whole in water, and then, by boiling the solution, evaporate a part of the water, and the muriate of soda, &c. fall down, while the salt-petre is held in solution. When the greatest part of these salts is thus separated, the remaining liquor is suffered to cool, and the nitre is obtained in crystals. This process illustrates the difference which there is in the solubility of salts.—*Parkes.*

Why was nitre used in the composition of Greek-fire?

Because it fed or kept alive the sulphur, resin, alcohol, camphor, &c. of which the fire was also composed, by conveying oxygen from the atmospheric air to the sulphurous gas, and to the sulphur while burning. Into this composition, when melted, woollen cords were dipped, and rolled up for use. These balls being set on fire, were thrown into the tents of the enemy, and as the combustibles were furnished with a constant supply of oxygen from the nitre, nothing could extinguish them.

Why will a lump of alum in a glass of water, assume a pyramidal shape in dissolving?

Because, at first the water acts with so much energy as to overcome the cohesion of the solid in every direction; but, as the particles of the alum become united with those of the water, the power of the solvent diminishes. The particles of water which combine first with the alum, become heavier by the union, and fall to the bottom of the glass; and the action at the lower extremity ceases, before it is complete at the upper. When the action has nearly terminated, if we closely examine the lump, we shall find it covered with geometrical figures, cut out, as it were, in relief, upon the mass; showing, not only that cohesion resists the power of solution, but that, in the present instance, it resists it more in some directions that in others; and that when the attraction of the solvent is nearly satisfied, it is balanced by that delicate modification of cohesion, upon which crystalline arrangement depends. This experiment beautifully illustrates the opposite action of cohesion and repulsion.

Why is alum used in making candles?

Because it gives firmness to the tallow.

Nitre has very recently been applied to the improved preparation of candles, by steeping the cotton wick in lime water, in which is dissolved a considerable quantity of nitre. By this means is obtained a purer flame and a superior light; a more perfect combustion is ensured; snuffing is rendered nearly as superfluous as in wax-lights; and the candles thus made do not run, or waste. The wicks should be thoroughly dry before the tallow is put to them.—*Brewster's Journal*, 1829.

Why is alum used in salt-drying cod-fish.

Because it prevents the salt from dissolving.

Why is alum used for preparing paper for the preservation of gunpowder?

Because it prevents the bad effects of damp atmospheric air upon the powder, and preserves the paper from readily taking fire.

Why are the crystals collected in camphor bottles in druggists' windows always most copious upon the surface exposed to the light?

Because the presence of light considerably influences the process of crystallization. Again, if we place a solution of nitre in a room which has the light admitted only through a small hole in the window-shutter, crystals will form most abundantly upon the side of the basin exposed to the aperture through which the light enters, and often the whole mass of crystals will turn towards it.—*Brande.*

Why is there rock salt?

Because it is supposed to have been deposited by the sea, or by salt lakes drying up, which formerly covered the present continents. Salt strata also diminish in thickness as they recede from the sea. This is perhaps the most obvious hypothesis, but it is liable to many objections, one of which is the enormous depth of sea water necessary to the production of a body of rock salt above forty yards in thickness, such as the insulated mountain of rock salt at Cordova, in Spain."—*Notes on Science.*

The salt mines near Cracow, in Poland, which have been worked ever since the middle of the thirteenth century, contain an immense store of muriate of soda. Eight hundred workmen are employed in them, who raise 168,000 quintals of salt annually. Through the enormous mass of salt, which presents to the eye no interruption to its saline texture, and at the depth of 450 feet, flows a stream of pure, fresh, and transparent water, which is received in large troughs, where the workmen and horses of these subterraneous regions quench their thirst. As it was impossible that this spring could filter through the salt, Nature, who buries her masterpieces in the bowels of the deepest mountains, has placed in this mass a stratum of clay sufficiently thick to allow the stream of water, destined to refresh the workmen, to pass through it in such a manner as to be preserved from the salt, of which a small quantity would injure its salubrity.—*Parkes.*

A series of ingenious models of the Polish salt mines was exhibited in London about two years since.

Why are the flats cut near the sea, on the Kentish coast, called salt-pans?

Because at high tide they become filled with sea-water, which being confined there, the sun evaporates it, and leaves salt in the flats, from whence it is laid up to dry for use.

Why is sugar refined by boiling the syrup in a vacuum, or place from which the air has been excluded?

Because this, and all other liquids, are driven off, or made to boil at lower degrees of heat when the atmospheric pressure is lessened or removed. Thus, the process for refining sugar is to dissolve impure sugar in water, and after clarifying the solution, to boil off or evaporate the water again, that the dry crystallized mass may remain. Formerly this evaporation was performed under the atmospheric pressure, and a heat of 218° or 220° was required to make the syrup boil; by which degree of heat, however, a portion of the sugar was discoloured and spoiled, and the whole product was deteriorated.

The syrup, during the process *in vacuo*, is not more heated than it would be in a vessel merely exposed to a summer sun. The vacuum is produced and maintained by air-pumps driven by a steam engine, or otherwise; or by the direct admission of steam, which, after expelling the air, is condensed into water.—*Arnott.*

By this process more money has been made in a shorter time, and with less risk and trouble, than was ever perhaps gained from an invention!

Why are the vessels for evaporating or distilling in vacuo, generally of arched form?

Because they require to be strong enough to bear, when quite empty, the external atmospheric pressure. —*Arnott.*

Why is sugar-candy crystallized on strings, and verdigris on sticks?

Because crystallization is accelerated by introducing into the solution a nucleus, or solid body, (like the string or stick) upon which the process begins.

The ornamental alum baskets, whose manufacture was once so favourite a pursuit of lady-chemistry, were made upon this principle; the forms of the baskets being determined by wire framework, to which the crystals readily adhered.

Why is sugar-candy sometimes in large and regular crystals?

Because the concentrated syrup has been kept for several days and nights *undisturbed*, in a very high temperature; for, if perfect rest and a temperature of from 120° to 190° be not afforded, regular crystals of candy will not be obtained.

The manufacture of barley-sugar is a familiar example of crystallization. The syrup is evaporated over a slow heat, till it has acquired the proper consistence, when it is poured on metal to cool, and when nearly so, cut into lengths with shears, then twisted, and again left to harden.

Why are small, radiant, and tree-like crystallizations seen on dirty windows in London?

Because of the great number of coal fires in the metropolis: these crystals (of sulphate of ammonia, or at least, sulphite of ammonia, which becomes sulphate by exposure to the air) being an abundant product of the combustion of coal.—*Brande.*

Why do some springs petrify objects by their spray?

Because their water is impregnated by means of its carbonic acid, with a large portion of carbonate of lime, which it deposits on issuing into the air. At Clermont, in France, there is such a spring, where Mr. Scrope saw the stuffed skins of a horse and a cow, birds, fruit, flowers, &c. undergoing this petrifying process. Its incrustations have also formed an elevated natural aqueduct, 240 feet in length, and terminating in an arch thrown across the stream it originally flowed into, 16 feet high and 12 wide.—*Scrope's Memoir on the Geology of Central France.*

Why is fluor spar so called?

Because it has the property of increasing the fusibility of other mineral substances. It has also been called *vitreous* spar, because when fused it has the appearance of glass.

HEAT.

Why is heat considered one of the chief agents in chemistry?

Because its most obvious sources are chiefly referred to the general head of chemical combination. Thus, fire, or the combustion of inflammable bodies, is nothing more than a violent chemical action attending the combination of their ingredients with the oxygen of the air. Animal heat, is, in like manner, referable to a process bearing no remote analogy to slow combustion, by which a portion of *carbon*, an inflammable principle existing in the blood, is united with the oxygen of the air in respiration, and thus carried off from the system: fermentation is nothing more than a decomposition of chemical elements loosely united, and their reunion in a more perfect state of combination. Friction, as a source of heat, is well known: we rub our hands to warm them, and we grease the axles of carriage-wheels to prevent their setting fire to the wood. Again, Count Rumford has established the extraordinary fact, than an unlimited supply of heat may be derived by friction from the same materials.—*J. F. W. Herschel.*

Savages light their fires by rubbing two pieces of wood: Count Rumford made great quantities of water boil, by causing a blunt borer to rub against a mass of metal immersed in the water; and Sir Humphry Davy quickly melted pieces of ice by rubbing them against each other, in a room cooled below the freezing point. Instances have occurred, where whole forests have been burned down by fires kindled from the violent friction of the branches against each other by the wind.

Why is it conjectured that there is a difference between solar and terrestrial heat?

Because the rays of the first pass through glass without heating it, while the rays of the latter are stopped by the glass, which becomes hot when opposed to them.

Why may heat be considered as a power opposed to attraction?

Because it tends to separate the particles of bodies; and whenever a body is heated, it is also expanded.—*Brande.*

Why is the term caloric used?

Because it may distinguish the cause of heat from the sensation which we call by the same name; but the terms *caloric* and *calorific fluid* seem to imply the material nature of heat, which has not yet been proved.

Why is caloric considered a subtle material fluid, the particles of which mutually repel each other?

Because this supposition appears to give a plausible explanation of most of the phenomena dependent upon heat, as the expansion, fusion, and vapourization of bodies, on the idea that the particles of caloric when interposed between the particles of bodies, in sufficient quantity, produce these effects. It is natural to suppose when a body is enlarged in bulk, that the enlargement is occasioned by the introduction of the particles of other matter, by which the particles of the expanded body are repelled to a greater distance from one another; and this repulsion becomes so great, in consequence of the introduction of a large quantity of heat, as to enable the particles of solid bodies to assume the fluid, or aëriform states.

There are, however, other theories of the nature of heat; but the question remains undetermined; and it is fortunate that most of the phenomena connected with the operation of heat, may be explained equally well upon either theory.

Why is heat called latent?

Because, when heat liquefies a solid, or converts a liquid into vapour, the liquid or the vapour is no *hotter* than the solid or liquid from which it was produced, though a great deal of heat has been expended in producing this effect, and has actually entered into the substance. Hence it continues to exist in the product, maintaining it in its new state without increasing its temperature, and is thus *latent* or hidden. This great discovery was made by Dr. Black, who further proved, that when the vapour condenses, or the liquid freezes, this latent heat is again given out from it.

Why does water thrown upon a fire so powerfully repress it?

Because of the great quantity of heat latent in steam;—hence, again, why *fire* and *water* are so often adduced proverbially as furnishing a striking contrast. —*Arnott.*

Why does iron become red-hot by hammering?

Because of the condensation of the metal by the force of the blow. Air may also be condensed by pressure, so as to set tinder on fire.

Why are inorganic bodies, such as gold, iron, &c. found in all parts of the globe?

Because they have no direct dependence, in the present state of the earth, at least, on the solar heat, or its consequences; whereas organic, or living matter, has.

Why does ice, when heated, become water; and the water, when heated further, become steam?

Because the continued addition of heat gradually increases the mutual distance of the constituent atoms of the ice, and their cohesive attraction is overcome; till, at length, the atoms are repelled to still greater distances, and the substance is converted into steam! Abstraction of heat causes return of states in the reverse order; the steam when cooled again, becomes water as before, and the water, when cooled, becomes ice.

Why does a pint of water, when converted into steam, occupy nearly 2000 times the space of the water?

Because the heat merely produces a repulsion among the particles, and by no means fills up the interstices.—*Arnott.*

Why are air-expansion engines so much more powerful than steam-engines?

Because heat, when used to dilate air, produces about four times the quantity of expansive power that it does when used to form steam.

Why is not high-pressure steam issuing from a boiler heated perhaps to 300° not hotter than low-pressure steam from a boiler at 212°?

Because, in the instant when the high-pressure or condensed steam escapes into the air, it expands until balanced by the pressure of the atmosphere; that is, until it become low-pressure steam, and it is cooled by the expansion, as air is cooled on escaping from any condensation.

Why does not a generator, if cracked when very hot, immediately let out the vapour or water?

Because the heat repels the water and vapour to a certain distance from the metal, and, virtually, stops the crack, until the temperature is allowed to fall, when the rush of steam by the crack is tremendous. Mr. Perkins, in reasoning upon this effect, says: "The repulsive power of the heated metal is sufficient to retain the *vapour* and the water equally distant; for, what else is vapour than water in a state of expansion?"

Why does a Prince Rupert's Drop fly to powder on being simply broken?

Because it is a lump of glass let fall, while fused into water, and thereby suddenly cooled and solidified on the outside, before the internal part is changed; then as this at last hardens and would contract, it is kept extended by the arch of external crust to which it coheres. Now, if a portion of the neck of the lump be broken off, or if other violence be done, which jars its substance, the cohesion is destroyed, and the whole crumbles to dust with a kind of explosion.—*Arnott.*

Why does a loose bladder, tied at the mouth, and held before a fire, gradually swell and appear fully inflated?

Because the small quantity of air contained in the bladder is then so much dilated by the heat, that it occupies a considerably increased space, and fills the bladder, of which it before occupied only a small part.

Why does change of temperature retard or hasten the decomposition of dead vegetable and animal substances?

Because the functions of life bring into combination, to form the curious textures of organic or living bodies, chiefly four substances, viz. *carbon*, or coal; the ingredients of water, or *oxygen* and *hydrogen;* and lastly, *nitrogen;*—which substances, when in the proportions found in such bodies, have but slight attraction for each other, and all of which, except the *carbon*, usually exist as airs. Their connexion, therefore, is easily subverted, and particularly by a slight change of temperature, which either so weakens their mutual hold as to allow new arrangements to be formed, or altogether disengages the more volatile of them.—*Arnott.*

Why is iron preserved from rust by dipping it when at a dull red heat, into water, and then into linseed oil?

Because the first part of the process frees it from the scales and extraneous matter, and the remaining heat disposes it to receive the oil, which forms a varnish, and filling up all the minute interstices of the surface, prevents any rust.

Why do clocks and watches vary in their rate of going?

Because of the expansion and contraction of the metals of which they are constructed. Thus, in regulating the length of the second's pendulum, an exact acquaintance with the dilatation of metals, is essential; for when the bob is let down a hundredth part of an inch, the clock loses ten seconds in twenty-four hours; hence, a thousandth part of an inch will cause it to lose one second per day, and a change of temperature equal to 30° of Fahrenheit will alter its length about one five thousandth part, and occasion an error in the rate of going, of eight seconds per day. Variations of temperature also occasion variations in the balance-wheels of watches, which are obviated by various compensating apparatus.

Why does a compensation balance prevent the effects of expansion or contraction?

Because it consists of interrupted concentric rings of different metals, joined together, so that the expansion of one counteracts the expansion of the other.

Why do the iron hoops of brewers' casks bind with such great force?

Because those which are at first made too small to fit, are heated until they are sufficiently enlarged; they are then driven on, and suddenly cooled, by throwing water upon them; the contraction of the iron which ensues on cooling, bringing the parts of the vessels in closer contact than they could easily be brought by other means, and fixes the hoops firmly round them.

Why does hay, if stacked when damp, take fire?

Because the moisture elevates the temperature sufficiently to produce putrefaction, and the ensuing chemical action causes sufficient heat to continue the process; the quantity of matter being also great, the heat is proportional.

Why are concave mirrors employed as burning-glasses?

Because they collect the heat of the sun's rays from the whole of its surface to a single point, thus accumulating a very great degree of heat, for the combustion and fusion of various natural substances, that are fusible in the greatest heat capable of being produced from ordinary fire. By this means, Drs. Harris and Desaugliers melted a silver sixpence in seven seconds and a half; a copper halfpenny melted in sixteen seconds, and liquefied in thirty-four seconds; tin was melted in three seconds; and a diamond weighing four grains, lost seven-eighths of its weight. Buffon also, with the faint rays of the sun in the month of March, set on fire boards of beech-wood at a hundred and fifty feet distance; and at another time, silver was thus fused at fifty feet distance.

Why are not "inflammable" and "combustible" synonymous terms?

Because all metals are combustible; that is, capable of igniting with oxygen: but they will not burn in atmospheric air, and are therefore not called inflammable.

Why does the thermometer enable us to ascertain degrees of heat?

Because the fluid ascends in the tube on being expanded by heat, and thus marks the degree.

Why is mercury preferred in thermometers?

Because the range of temperature between its freezing and boiling points is very considerable; and its expansion within that range, tolerably equable.—*Brande.*

Why have thermometers freezing and boiling points?

Because they denote the points in the tube at which the mercurial column stands when cooled to the freezing, and heated to the boiling, of water. For this purpose, the instrument is immersed in melting ice or snow, and permitted to remain there for some time, until the quicksilver becomes stationary at one place, which is the *freezing point;* a mark is made at that point upon the glass. If the instrument remains for some time in boiling water, the mercury after having ascended through a large proportion of the tube, becomes stationary at one place which is the *boiling point.* It is believed that Fahrenheit took his *zero*, or commencement of his scale from the degree of cold produced by mixing snow and common salt; that being the greatest degree of cold known in his time; although a considerably greater degree of cold may be produced by mixing the same or other ingredients.

Why does Reaumur's thermometer differ from Fahrenheit's?

Because Reaumur divides the space between the boiling and freezing points into 80 degrees, placing zero at freezing, and the 80th degree at the boiling point.

Fahrenheit divides the same space into 180 degrees; but the cipher (0) he places 32 degrees below the freezing point (the cold of a mixture of snow and common salt) so that the freezing point is at 32° and the boiling point at 212°.

Reaumur 80°)180° Fahrenheit

2¼° of Fahrenheit—equal to 1°
of Reaumur.

Plus 20° of Reaumur is 20° multiplied by 2¼=45 add 32°=77° of Fahrenheit.

Why are spirit thermometers preferable for measuring very low temperatures?

Because spirit never freezes, whereas the low temperature at which it boils, renders it unfit for measuring high temperatures.

Why do dogs and other animals put out their long moist tongues in hot weather?

Because, when much heated, they cannot throw off or diminish their natural covering, and have only the above means of increasing the evaporation from their bodies.

Why, in the Arctic Regions, are the watery parts of brandy frozen, while a very small quantity of strong *spirit is left in the fluid state in the interior of the mass?*

Because the cohesion of the particles of water is so much more increased by the cold than that of the particles of the spirit.

Why is a pyrometer so called?

Because of its origin from two Greek words signifying *measure of fire;* it being used to ascertain the degrees of heat in high temperatures, and including a range of nearly 32,000 degrees of Fahrenheit.

Why does metal feel cold when touched?

Because it readily carries off the heat of the body; all metals being good conductors of heat.

Why are certain bodies called good and bad conductors of heat?

Because, when exposed to the same source of heat, they suffer it to pass through them with different degrees of velocity; or they have various conducting powers with regard to heat. Good conductors, when touched, occasion a greater sensation of heat and cold than bad ones. When the body feels cold, the caloric is passing out of it into the neighbouring object: when the body feels warm, it is receiving heat.

Why are persons enabled to remain in a heated oven, wherein meat is baking?

Because of the rarity of the air, its weak conducting power, and its small capacity for caloric, which explain how a person can exist in so warm an atmosphere. The wool dresses which persons usually wear on such occasions, are also bad conductors of heat.

Sir C. Blagden, secretary to the Royal Society about thirty years since, remained, accompanied by a female dog, during eight minutes, in an oven heated to 100° of Reaumur, 20° above the point at which water boils; water, although covered with oil, boiled close to him; and in thirteen minutes, the hot air being concentrated by a pair of bellows, some beef was dressed in the same place. Two French academicians, of the last century, saw at Larochefoucault a man, who, from habit, supported during ten minutes the heat of an oven, in which fruits and meats were cooked; they found the heat to be 112° of Reaumur, 32° above that of boiling water. The rarity of the air, its weak conducting power, and its small capacity for caloric, serve to explain how a person can exist in so warm an atmosphere. It is by its action upon the skin, and the consequences which ensue from that, that fire becomes injurious. Now the "Fire King," who exhibited himself in London last spring, was wrapped up in wide pantaloons, of red wool, a loose mantle also of wool, and wore on his head a great quilted felt cap; and the wool being a bad conductor of heat, this wonder-working genius should awaken the astonishment of the ignorant alone.

Why are porous or spongy substances, as feathers, fleecy matter, &c. bad conductors of heat?

Because, in great measure, of the quantity of air which they have in their structure; air being, probably, the worst conductor known, that is, the substance which, when at rest, impedes the passage of heat the most.—*Arnott.*

Why does a drop of water roll about on a red-hot iron without evaporation?

Because its surface becomes so highly polished as to reflect all the heat. If the heat be less, the water penetrates the pores of the oxidated iron, and losing its polish is evaporated.

Why is water frozen in a vessel from which the air has been pumped out, and which contains bodies that quickly absorb its vapours?

Because the evaporation of the water is thus accelerated—the heat required for the conversion of one portion of the water into vapour, being taken from the other portion, which is thus reduced to ice.

Why is soft and flabby meat unfit for cooking?

Because, after the rigidity has totally ceased, animal flesh soon experiences the commencement of those chemical changes which terminate in putrefaction.

Why do confectioners melt ice with common salt?

Because they thus produce cold much greater than that of the original ice.

Why do not springs freeze?

Because the earth conducts cold or heat but slowly, and the most intense frosts penetrate but a few inches into it; the temperature of the ground, a few feet below its surface, is nearly the same all the world over.—*Arnott.*

Why are many of the gothic halls and cathedrals cool in summer and warm in winter?

Because, in proportion as buildings are massive, they acquire more of those qualities, which have just been noticed, of our mother-earth.—*Arnott.*

Why is the degree of cold greater the farther we remove from the earth's surface?

Because the air is not heated immediately by the rays of the sun passing through it; but on their meeting with an opaque (or dense) body, as the earth, their heat is elicited, and thence gradually communicated to the surrounding atmosphere.

In winter, the earth, at eighteen inches depth, is warmer than the air; in summer, the air is warmer than the earth at that depth: these effects are owing to the earth being a bad conductor of heat.—*Parkes.*

Why do the Swiss peasants, when they wish to sow their seed, spread black cloth on the surface of the snow?

Because it may absorb the sun's rays, and facilitate the melting of the snow. Dr. Franklin, to exemplify the effect of the different colours in absorbing heat, covered snow with pieces of cloth of different colours, at a time when the sun was shining fully upon the snow. Having done so, he observed that the snow under the black cloth was melted first, then that under the blue, then under the brown, whilst that under the white cloth was very inconsiderably melted.

Why are the heights of mountains calculated by the temperature at which water boils upon their summits?

Because, if we diminish atmospheric pressure, we lower the boiling point. Thus, water, under mean atmospheric pressure of 30 inches of mercury, boils in a metallic vessel at 212°. At the top of Mont Blanc, Saussure found that it boiled at 187°, from the atmosphere being less dense there than below.

Why is the air warm in misty or rainy weather?

Because of the liberation of the latent heat from the precipitated vapour.

Why is heated air thinner or lighter than cold air?

Because it is a property of heat to expand all bodies; or rather we should say, that we call air hot or cold, according as it naturally is more or less expanded.

Why is a tremulous motion observable over chimney-pots, and slated roofs which have been heated by the sun?

Because the warm air rises, and its refracting power being less than that of the colder air, the currents are rendered visible by the distortion of objects viewed through them.

Within doors, a similar example occurs above the foot-lights of the stage of a theatre; the flame of a candle, or the smoke of a lamp.

Why are the gas chandeliers in our theatres placed under a large funnel?

Because the funnel, by passing through the roof into the outer air, operates as a very powerful ventilator, the heat and smoke passing off with a large proportion of the air of the house.

The ventilation of rooms and buildings can only be perfectly effected, by suffering the heated and foul air to pass off through apertures in the ceiling, while fresh air, of any desired temperature, is admitted from below. —*Brande.*

Why is the atmosphere of theatres, and other crowded places, prejudicial to health?

Because it has been found, that in a theatre, from the commencement to the end of the play, oxygen or vital air is diminished in the proportion of from 21 to 27, or nearly one-fourth, and is in the same proportion less fit for respiration than before.—*Lavoisier.*

Why are diving-bells restricted in their descent to ten or twelve fathoms?

Because of the density, and more especially the heat, of the air, although renewed by forcing pumps, becoming insupportable.

Why does the bark of trees resemble clothing?

Because it allows the heat to pass from the tree but slowly, and secures, therefore, the temperature necessary to vegetable life.

That caloric is as necessary for the support of vegetable as it is for that of animal life, may be proved by direct experiment. If, in the middle of winter, a hole be bored in a tree, and a thermometer put into it, it will be seen that the tree is many degrees warmer than the atmosphere.

Why does the effect of wind, or motion of the air, quicken evaporation?

Because it removes air saturated with the moisture, and substitutes air which is not, thus producing nearly the case of the substance placed in a vacuum.

Why do liquids evaporate neither so rapidly nor so greatly in air, as in a vacuum?

Because the presence of the air impedes the spreading from the liquid surface of the newly-formed vapour, and keeps it where its pressure resists the formation of more vapour; and, because the air in contact with a liquid, shares its higher temperature with the liquid. Still, in India, flat dishes of water, placed through the night on beds of twigs and straw, kept wet, and in a current of air, soon exhibit thin cakes of ice—and thus ice is procured in India, for purposes of luxury.—*Arnott.*

Why do heated sea-sand and soda form glass?

Because, by heating the mixture, the cohesion of the particles of each substance to those of its own kind is so diminished, that the mutual attractions of the two substances come into play, melt together, and unite chemically into the beautiful compound called glass.

Why is sand used in glass?

Because it serves for stone; it being said, that all white transparent stones which will not burn to lime are fit to make glass.

Why do cracked glass vessels allow liquors to escape more or less?

Because of the various fissures, which are distinguished into four kinds. The first are such, that the liquid contained in the broken vessel escapes through them into the air. The second are such as retain the liquid, unless the vessel be immersed in water, or a similar fluid, and then the levels of the two portions of the fluid, tend to approach each other. The third are not permeable, (or, to be passed through) unless the fluids on opposite sides have a chemical action on each other: this is also the effect produced by the membrane of the bladder. The fourth kind are so fine, that no fluid passes, except in a single case.—*Fischer.*

Why is fine table-glass very liable to wear and damage?

Because of the great quantity of oxide of lead which it contains, to give it more density and refractive power. Its disadvantages are extreme softness, great fusibility, and liability to be corroded by acids. A considerable quantity of this oxide is contained in that glass used for lustres, for artificial gems, and for most optical purposes. The superior appearance of Guinand's Swiss flint-glass is attributed to the quantity of oxide of lead which it contains.

ELECTRICITY.

Why is electricity so calld?

Because of its origin from *electron*, the Greek name of amber,—the phenomena displayed by rubbing a piece of amber, being the first physical fact recorded in the history of science.

Electricity investigates the attractions and repulsions, the emission of light and explosions, which are produced not only by the friction of vitreous, resinous, and metallic surfaces, but by the heating, cooling, evaporation, and mutual contact of a vast number of bodies.

Why are certain bodies called conductors of electricity?

Because they suffer electricity to pass through their substance. The metals are all conductors; according to Mr. Harris, (*Phil. Trans.* 1827) silver and copper are the best conductors; then gold, zinc, and platinum, iron, tin, and lead. Well burned charcoal and plumbago also conduct.

Why are other bodies called non-conductors?

Because they only receive electricity upon the spo touched. Dry air, glass, sulphur, resins, and oils, are non-conductors. Water, damp wood, spirit of wine, damp air, some oils, and most animals and plants, are imperfect conductors.

Why have different bodies various conducting powers for electricity?

Because their degree depends on the quantity of electricity which traverses them; so that of two conducting bodies, that which is the best for one electric current, may be the worst for either a stronger or a weaker current.—*Professor Delarive, of Geneva.*

Why are the phenomena of electricity called negative and positive?

Because, Franklin, observing that the same electricity was not inherent in the same body, but that glass sometimes exhibited the same phenomena as wax, and wax as glass, instead of regarding the phenomena as dependent upon two electric fluids, referred them to the presence of one fluid, in excess in some cases, and deficient in others. To represent these states, he used the terms *plus* and *minus*, *positive* and *negative*. Thus, when glass is rubbed with silk, a portion of electricity leaves the silk and enters the glass; it becomes positive, therefore, and the silk negative: but when sealing-wax is rubbed with flannel, the wax loses and the flannel gains; the former, therefore, is negative, and the latter positive. All bodies in nature are thus regarded as containing the electric fluid; and when its equilibrium is disturbed, they exhibit the phenomena just described.—*Brande.*

Why does an electrical machine produce flashes and sparks of light, when the plate or cylinder is turned?

Because, it is conjectured, of the sudden compression of the air, or medium, through which the electricity passes: it is, probably, always attended by a proportionate elevation of temperature, as is shown by the power of the spark to influence spirits of wine, fulminating silver, and other easily inflammable compounds. —*Brande.*

Why will a feather adhere to rubbed or excited sealing-wax, and then fall off?

Because it is attracted by, and remains in contact with, the wax, till it has acquired its electricity, when it will be repelled, and in that state of repulsion, it will be attracted by an excited glass tube.

Why does the appearance of electric fire vary?

Because of the different density of the medium through which it passes. Thus, in common air, short sparks are straight, or nearly so, and long ones zig-zag; the former are brilliant, especially at their extremities, the latter usually of a paler or redder hue. In condensed air, the electric spark is bright and white; in rarified air it is of a reddish tinge, and faint and divided; in the more perfect vacuum of a good air-pump, it is of a purplish hue, and only visible in a dark room. In the most perfect vacua which can be obtained, it is scarcely visible, and of a greenish tint. In different gases the electric spark appears most brilliant in those which are most dense; in hydrogen gas it is faint and red; in carbonic acid it is vivid and white.—*Brande.*

Why is the electrical shock produced at the joints of the fingers, the elbows, shoulders, and chest, by holding the discharger of a Leyden phial?

Because there is an accumulation of electricity within the phial, which consists of a thin glass jar, coated internally and externally with tin-foil, to within a short distance of its mouth. When the inner surface is rendered positive by union with the conductor of the electrical machine, the exterior, being connected with the ground, becomes negative by vicinity or position. When the inner and outer surfaces are united by a conductor, all electrical accumulation is annihilated by a powerful spark, and the two opposite states are found to have been precisely equivalent. Metallic wires, with balls at their ends, bent or jointed, and fixed to a glass handle, are generally used to transfer the electric charge, and these instruments are called *dischargers*. A pane of glass, coated upon both sides to within an inch of its edges, with tin-foil, exhibits precisely the same phenomena as the phial; but it is a less convenient form of the apparatus.—*Brande.*

Why does the aura (or wind of an electrical machine) blow out a candle?

Because of the rapid succession of the electrified air. This effect is felt upon holding the hand near the point of a wire affixed to the conductor, when a peculiar coldness is perceived. It communicates motion to light bodies, as is seen in electrical fly-wheels, and in models of mills, orreries, and other amusing electro-mechanical apparatus.

Why is an arrangement of several Leyden jars called an electrical battery?

Because by a communication existing between all their interior coatings, their exterior being also united, they may be charged and discharged as one jar.

The discharge of the battery is attended by a considerable report, and if it be passed through small animals, it instantly kills them; if through fine metallic wires, they are ignited, melted, and burned; and gunpowder, cotton sprinkled with powdered resin, and a variety of other combustibles, may be inflamed by the same means.

Why is light produced in the empty part of a barometer tube, when it is shaken in a dark room?

Because the glass becomes electrified by the friction of the mercury. Even the friction of air upon glass is attended by electrical excitation: for it has been found, that by blowing upon a dry plate of glass, with a pair of bellows, it acquired positive electricity.

Why is a plate of zinc, when brought into contact with one of copper, or silver, found, after removal, to be positively electrical, and the silver or copper left in the opposite state?

Because of the electrical excitation by contact of the different metals, the most oxidizable (liable to rust) metal being always positive in relation to the least oxidizable metal, which is negative; and the more opposite the metals in these respects, the greater the electrical excitation; and if the metals be placed in the following order, each will become positive by the contact of that which precedes it, and negative by the contact of that which follows it, and the greatest effect will result from the contact of the most distant metals.

Platinum
Gold,
Silver,
Mercury,
Copper,
Iron,
Tin,
Lead,
Zinc.

Why are brass cocks in leaden cisterns corroded at the junction?

Because of the chemical effects of the contact of the metals. In like manner, the places where solder is applied are liable to depositions from the water. Iron railings are apt to be decayed and dissolved, where lead is used to fix them in stone cavities; and where iron is employed in fixing a bronze statue, my friend Mr. Chantrey (observes Mr. Brande) informs me that it prevents the acquisition of the desirable green rust.

Why have copper been substituted for iron nails and pins in fastening sheets of copper to ships' bottoms?

Because the galvanic action produced by the union of the two metals, iron and copper, was a great cause of destruction; and copper nails and pins, although not so strong, are not attended with the same inconvenience.

The last experiments which engaged Sir Humphry Davy's attention to any extent, were on this application of electrical combinations, for the purpose of preserving the copper sheathing of ships' bottoms. To this subject Sir Humphry Davy gave much of his time, and personally inspected all the boats and vessels on which the trials were made. Although the theory upon which they were conducted proved eminently correct, no advantage could be ultimately taken of the plans which it suggested. The saving of the copper was wholly counterbalanced by an accumulation of shell-fish and sea-weed on the sheathing, which became sufficient, in a short time, to prevent the proper command of the ship at the helm.

Why is electricity supposed to consist in a rare, subtle, and highly elastic fluid?

Because a fluid of this kind, when accumulated in excess in bodies, tends constantly to escape, and seeks a restoration of equilibrium by communicating itself to any others where there may be a deficiency; thus, in its tendency to expand and diffuse itself, pervading with more or less facility the substance of conductors, but obstructed and detained from expansion more or less completely by non-conductors. It also appears that all electrical phenomena are explicable on this supposition.

Why is animal electricity also called galvanism?

Because of its discovery by Galvani, by the accidental suspension of recently killed frogs, by copper hooks, to the iron palisades of his garden, when he observed convulsive movements in the limbs of the animals, which no known principle could explain. Galvani, at length, ascribed these muscular movements to a series of discharges of a peculiar electricity, inherent and innate in living beings.

Why were the phenomena just mentioned, called Voltaic electricity?

Because Volta proved that they proceeded from the contact of the two dissimilar metals (of the hooks and palisades) copper and iron, producing such a disturbance of the electrical equilibrium as was sufficient to affect the most delicate of all electroscopes, (measures of electricity) the irritability of a newly-killed frog, though it was insensible to every electroscope of human construction. Galvani, however, proved that muscular convulsions could be produced in the limbs of dead frogs, altogether independent of metals.

Galvanism has of late years given birth to improvements that have changed the face of chemical philosophy. One of its most brilliant results is thus beautifully illustrated in a Treatise "on the objects, advantages, and pleasures of science," attributed to the present Lord Chancellor:—"It is to the results of the remark accidentally made upon the twitching in the frog's legs, not, however, hastily dismissed and forgotten, but treasured up and pursued through many an elaborate experiment and calculation, that we owe our acquaintance with the extraordinary metal, liquid-like mercury, lighter than water, and more inflammable than phosphorus, which forms, when it burns, by mere exposure to the air, one of the salts best known in commerce, and the principal ingredient in saltpetre."

Why was the Voltaic pile first constructed?

Because a slender rod of silver and of zinc, touching each other at one of their ends, and at the other brought into contact with the nerve and muscle, or spine and toes of a dead frog, having excited powerful convulsions, it occurred to Volta that a repetition, on a more extended surface, of that simple series of two metals and moisture, might produce a combined effect, capable of being felt by the human hand. Hence, he constructed, by regular alternations of silver, zinc, and moistened cloth or pasteboard, in a columnar form, the electro-chemical pile and battery. The best form of the Voltaic instrument is, however, that of a trough of earthenware, with divisions of the same material, (to be filled with dilute acid); and the metallic plates are attached to a bar of wood, so that they can be immersed and removed at one operation. Such is the great apparatus of the Royal Institution, the most powerful battery yet constructed in *electro-chemical intensity*. The whole surface is 128,000 square inches.

Mr. Pepys likewise constructed a battery of 2000 plates for the London Institution; and Mr. Children constructed a vast apparatus, the plates of which were two feet eight inches wide, and six feet high. They were fastened to a beam suspended by counterpoises from the ceiling of his laboratory, so as to be easily immersed into, or withdrawn from, the cells of the acid.—*Brande.*

There are six great eras in *electro-chemical science:* —1. Its first discovery by Galvani. 2. Volta's discovery of the contact of dissimilar metals disturbing the electric equilibrium. 3, Volta's invention of the pile. 4. The *chemical* power of this instrument first observed by Messrs. Carlisle and Nicholson, in the decomposition of water. 5. The identity of these chemical effects with those producible by common electricity, first discovered and demonstrated by Dr. Wollaston. And, lastly, the general laws of electro-chemical decomposition and transfer, revealed by Sir Humphrey Davy in a series of memoirs equally remarkable for genius and industry.—*Ure.*

Why is electricity continually active in nature?

Because general changes in the form and constitution of matter, are connected with its electrical states.

Why does it lighten?

Because of the accumulation of electricity in the clouds: hence it is, in philosophical parlance, called the *electric fluid.*

The discharge of electricity in a thunder-storm, is sometimes only from cloud to cloud; sometimes from the earth to the clouds; and sometimes from the clouds to the earth, as one or other may be positive or negative. When aqueous vapour is condensed, the clouds formed are usually more or less electrical; and the earth below them being brought into an opposite state, a discharge takes place when the clouds approach within a certain distance, constituting *lightning.*—*Brande.*

Why does it thunder?

Because of the undulation of the air, produced by the electric discharge just mentioned; thunder being more or less intense, and of longer or shorter duration, according to the quantity of air acted upon, and the distance of the place where the report is heard from the point of the discharge.

Mr. Brande, from whom we quote this explanation, gives a further illustration of this idea:—"Electrical effects take place in no sensible time: it has been found that a discharge through a circuit of four miles is instantaneous; but sound moves at the rate of about twelve miles in a minute. Now, supposing the lightning to pass through a space of some miles, the explosion will be first heard from the point of the air agitated, nearest to the spectator; it will gradually come from the more distant parts of the electricity, and, last of all, will be heard from the remote extremity: and the different degrees of the agitation of the air, and likewise the difference of the distance, will account for the different intensities of the sound, and its apparent reverberations and changes."

Sir H. Davy, in his *Elements*, says: "In a violent thunder-storm, when the sound instantly succeeds the flash, the persons who witness the circumstance are in some danger; when the interval is a quarter of a minute, they are secure."

Why are pointed conductors fixed as safeguards to buildings?

Because the fluid or lightning may be attracted and circulated along them, and thus kept from injuring the building, till at length it reaches the earth as a common reservoir.

In these cases, the conducting rod or rods should be of copper or iron, and from half to three-fourths of an inch in diameter. Its upper end should be elevated three or four feet above the highest part of the building, and all the metallic parts of the roof should be connected with the rod, which should be perfectly continuous throughout, and passing down the side of the building, penetrate several feet below its foundation, so as always to be immersed in a moist stratum of soil, or, if possible, into water. The leaden water-pipes attached to houses often might be made to answer the purpose of conductors, especially when thick enough to resist fusion.—*Brande.*

The magnificent effects of electricity in the thunder-storm, were first experimentally demonstrated by Dr. Franklin, whose whole life was passed in ameliorating the condition of his fellow creatures.

Why is the fireside an unsafe place in a thunder-storm?

Because the carbonaceous matter, or soot, with which the chimney is lined, acts as a conductor for the lightning.

Why is the middle of an apartment the safest place during a thunder-storm?

Because, should a flash of lightning strike a building, or enter at any of the windows, it will take its direction along the walls, without injuring the centre of the room.

Why is bed a place of comparative safety in a thunder-storm?

Because blankets and feathers are non-conductors. A woollen rug is likewise a non-conductor, but it should be removed from the chimney. Bell wires being conductors, are almost always melted in houses struck by lightning.

Why is it dangerous to take shelter under a tree during a storm?

Because the tree is a good conductor, probably from vegetation tending to atmospheric electricity, and the immediate vicinity of the tree being more highly electrical, as will be presently shown, (*See page* 47.)

The safest situation without doors, during a storm, is within some yards of trees, and upon the dryest spot that can be selected.

Why are ships at sea so often destroyed by lightning?

Because of the great quantity of metal, and particularly of iron, which is employed in the rigging; more especially as the metallic masses are there nearly insulated, or connected only by very imperfect conductors.

These inferences are drawn from an interesting account of an accident to the packet ship the New York, by lightning, in 1827. The paper is by Dr. Trail, and was communicated to the Royal Society by one of its most distinguished fellows, the present Lord Chancellor. It will, of course, be found in the *Philosophical Transactions* of the year, but, perhaps, more readily, in the *Arcana of Science and Art* for 1829.

Why is copper a better material for a conductor than iron?

Because copper is less liable either to fusion or conversion. A rod is also, from its continuity, a better form of conductor than a chain.

Why are there "returning" strokes of lightning?

Because they are due to the restoration of the natural electric state, after it has been disturbed by induction. Thus, if a person be brought into a highly electric and negative state by induction, from the approximation of a body highly charged positively, and then the latter be discharged by means having no connexion with the negatively electrified person, the negative state of the latter will be immediately destroyed, and an effect, in part analogous to a positive discharge of electricity, will be produced. Some of the most serious accidents which occur from lightning are supposed to be produced in this way; not by the mere disturbance of electricity in a person only, but of the electricity of those bodies with which the person may be in contact, and to which he accidentally serves as a conductor.

For an illustrative narrative of a returning stroke of lightning, near Paris, in September, 1826, see a paper translated from the *Annales de Chimie*, in the *Quarterly Journal of Science* for 1826.

Why are vitreous tubes occurring in elevated sandy districts, called "lightning tubes?"

Because they have been considered as produced by lightning, which melts the sand to a considerable depth, so as to form a tube, commonly sinuous, with solid and smooth walls internally, and rough on the outside. In 1828, a young German naturalist presented to his academy some of these tubes seventeen feet in length. It has been asked how electricity could produce effects so intense, and which have been considered so different from those obtained from artificial electricity; but this point has been decided by two eminent French chemists' success in forming fragments of tubes perfectly resembling the natural lightning tubes, only that their walls were less solid, and their length less.

Why have the gymnotus, or electric eel, and the torpedo, or electric eel, a benumbing effect when touched?

Because of certain singularly constructed organs given to those remarkable animals for the purposes of defence, which certain forms of the Voltaic apparatus much resemble; for they consist of many alternations of different substances. These electrical organs are much more abundantly supplied with nerves than any other part of the animal, and the too frequent use of them is succeeded by debility and death.—*Philosophical Transactions*, 1817.

Towards the close of his valuable life, Sir H. Davy dated from Lubiana, Illyria, (1828) an important paper containing a summary of his experiments on the torpedo. It will be found in the *Philosophical Transactions* of the year. Among the inferences drawn by Sir Humphry, is "a stronger analogy between *common* and *animal* electricity, than between Voltaic and animal electricity; and a probability that animal electricity will be found of a distinctive and peculiar kind." This opinion, it will be perceived, is at variance with the explanation quoted in the preceding paragraph.

Again, Sir Humphry observes, "the organ of the torpedo depends for its powers upon the will of the animal. John Hunter has shown how copiously it is furnished with nerves. In examining the columnar structure of the organ of the torpedo, I have never been able to discover arrangements of different conductors similar to those in galvanic combinations; and it seems not improbable that the shock depends upon some property developed by the action of the nerves."

Why do vegetables tend to atmospheric electricity?

Because of the action of the charcoal they contain upon the oxygen of the air; and when it is considered that on one hand about fifteen grains of charcoal, in becoming carbonic acid, gives out sufficient electricity to charge a Leyden jar; and, on the other hand, that the charcoal which is contained in vegetables does not give out less electricity than charcoal which burns freely, one may conclude, as direct experiments tend to prove, that over a surface of vegetation, 100 metres square, more electricity is produced in a day than is necessary to charge the strongest electrical battery.—*M. Pouillet, in the Annales de Chimie.*

Why is electricity beneficial to plants?

Because electrified seeds pass more rapidly through the first periods of vegetation, than such as are not electrified; and electrified roses flower more rapidly and abundantly. Plants with pointed leaves and spines attract electricity.

Why is the cutting down of forests found to diminish the quantity of rain?

Because it is supposed to diminish the attraction for clouds.

Why do leeches die suddenly at the approach of or during storms?

Because of the coagulation of their blood, caused by the impression of the atmospheric electricity.

Why is electricity considered an important chemical agent?

Because it not only produces an infinite variety of changes, but likewise influences almost all which take place. Thus, there are not two substances on the surface of the globe that are not in different electrical relations to each other; and chemical attraction itself seems to be a peculiar form of the exhibition of electrical attraction; and wherever the atmosphere, or water, or any part of the surface of the earth gains accumulated electricity of a different kind from the contiguous surfaces, the tendency of this electricity is to produce new arrangements of the parts of these surfaces; thus, a positively electrified cloud, acting even at a great distance on a moistened stone, tends to attract its oxygenous or acidiform, or acid ingredients, and a negatively electrified cloud has the same effect upon its earthy alkaline, or metallic matter; and the silent and slow operation of electricity is much more important in the economy of nature, than its grand and impressive operation in lightning and thunder. The chemical agencies of water and air are assisted by those of electricity; and their joint effects, combined with those of gravitation, and certain mechanical ones, are sufficient to account for the results of time.—*Sir H. Davy's Consolations in Travel.*

Why are magnetism and electricity, which had long been studied as separate branches of science, now effectually blended?

Because all the phenomena of magnetic polarity, attraction, and repulsion, have at length been resolved into one general fact, that two currents of electricity moving in the same direction repel, and in contrary directions attract, each other.—*Herschel.*

Hence, the magnetic effects of electricity constitute a new branch of science, under the title of *electro-*

magnetism. The more popular phenomena of magnetism, which it will be our object to explain, do not, however, belong strictly to chemical inquiry; we may therefore reserve their illustration for a more fitting occasion.

LIGHT AND FLAME.

Why may light and air be said to constitute a portion of our earth?

Because of their absorption by the earth. Thus, the light emitted by burning coals, (which are generally admitted to be of vegetable origin) has undoubtedly been condensed in them by a process of nature which bids defiance to conjecture.—*Mr. Detrosier of Manchester.*

Why does a fire give out warmth?

Because the heat is *radiated;* there being but little connexion with the immediate conducting power of the air; thus, if a concave *metallic* mirror be held opposite the fire, a heating and luminous focus will be obtained.

Why is ice produced in India (as described in page 34)?

Because, chiefly, of the high radiating powers of the dry straw which is strewed in the inclosures, containing the water in shallow dishes. Calm and serene nights are most favourable to this operation, and it is necessary that the straw should be dry; for, when wetted, the production of cold is prevented; a circumstance which shows that evaporation is not the cause of the diminished temperature. We quote this from Brande, although the conclusions do not coincide with the opinion quoted from Arnott, at page 33.

Why are certain rays of the sun termed decomposing?

Because they have a tendency to interfere with the chemical constitution of bodies. Besides this kind of rays, it is ascertained there are two others; the calorific, or heating rays; and the luminous, or colourific rays; which produce vision and colour.

Sir H. Davy has, in some general facts of great interest, traced an analogy between the effects of the sun's rays and the agencies of electricity.

Why are the terms red-hot and white-hot used?

Because, when bodies are rendered luminous by great elevation of temperature, the light which they emit often appears dependent upon the heat to which they are subjected. There are, however, certain bodies which, at high temperatures, are remarkable for the quantity and extreme brilliancy of their light, independent of actual combustion; this is the case with several of the earths, but more especially with lime, a small ball of which, about a quarter of an inch in diameter, being ignited in the flame of alcohol urged by oxygen gas, emits light; having about thirty-seven times the intensity of an Argand lamp burner.—*Brande.*

Lieutenant Drummond has proposed to apply this principle to the improvement of the illumination of light-houses; by substituting "for the Argand burners a small ball of lime ignited by the combustion of oxygen and hydrogen." His experiments are described in the *Philosophical Transactions*, 1830, as follows:—

"From this small ball, only three-eighths of an inch in diameter, so brilliant a light is emitted, that it equals in quantity about thirteen Argand lamps, or 120 wax candles; while, in intensity or intrinsic brightness, it cannot be less than 260 times that of an Argand lamp. These remarkable results are deduced from a series of experiments made lately at the Trinity House; and, having been repeated with every precaution, and by different individuals, there seems no reason to doubt their accuracy. In the best of our revolving lights, such as that of Beachy Head, there are no less than thirty reflectors, ten on each side. If, then, a single reflector, illuminated by a lime ball, be substituted for each of these ten, the effect of the three would be twenty-six times greater than that of the thirty. On account of the smaller divergence of the former it would be necessary to double their number, placing them in a hexagon instead of a triangle. In this case the expense is estimated at nearly the same. This method was tried lately at Purfleet in a temporary lighthouse, erected for the purpose of experiments by the corporation of the Trinity House, and its superiority over all the other lights with which it was contrasted, was fully ascertained and acknowledged."

Why are light and heat necessary to the existence of plants?

Because, in the sunshine, vegetables decompose the carbonic acid gas of the atmosphere, the carbon of which is absorbed and becomes part of their organized matter; and the oxygen, which is the other constituent, is thrown off.

Why do not plants flourish in the dark?

Because no oxygen is then produced by them, and no carbonic acid absorbed.

Light exercises a very remarkable influence upon the irritability of the sensitive plant. Thus, if a sensitive plant be placed in complete darkness, by carrying it within an opaque vessel, it will entirely lose its irritability, and that in a variable time, according to a certain state of depression or elevation of the surrounding temperature.

Again, Mr. Burnet finds that when a sensitive plant has been made to droop, if the part in which the moving power resides is blackened so as to absorb the light of the sun, the restoration of the plant to its natural state is very much longer before it takes place. He also finds that at the moment the expansion at the foot of the leaflets, or other parts, is touched, to produce the motion of the plant, it changes colour.—*Philos. Mag.*

Why are certain bodies said to be phosphorescent?

Because, when heated to a certain point below incandescence, (an exceedingly high temperature without the production of any gas) they become luminous, without undergoing combustion. Oil, wax, spermaceti, and butter, when nearly boiling, are luminous.—*Brande.*

Why are other classes of phosphorescent bodies called solar phosphori?

Because they become luminous when removed into a dark room after having been exposed to the sunshine. Of this description are Canton's, Baldwin's, and the Bolognian phosphorus, the latter named from its discovery by a shoemaker of Bologna.—*Brande.*

Wöhler, a German chemist, recommends, as likely to give phosphorus at a very cheap rate, to distil, by a strong heat, ivory black with half its weight of fine sand and charcoal powder. A silicate of lime is formed, and the carbonic oxide and phosphorus come over.

Dr. Bache, of Philadelphia, states, that at the temperature of sixty degrees Fahrenheit, or upwards, carbon in the form of animal charcoal, or lamp-black, causes the inflammation of a stick of phosphorus powdered with it; the effect takes place either in the open air, or in a close receiver of a moderate size.

Bodies *spontaneously phosphorescent* belong to another class. Among these are the flesh of salt-water fish just before it putrifies, and decayed wood. The glow-worm and the lantern-fly, certain shell-fish, medusæ, &c. are also luminous when alive; and the hundred-legged worm, and some other worms and insects, shine brilliantly when illuminated. These phenomena, as well as the phosphorescence of the sea, will, however, be explained elsewhere.

The phosphorescence of fish has already been noticed, and attributed to animalculæ *during putrefaction;* whereas, from the experiments of Canton, and of Dr. Hulme, it appears that "sea-fish become luminous in about twelve hours after death, that it increases till putrefaction is evident, and that it then decreases."

Why may flame in general be regarded as luminous gaseous matter?

Because hydrogen gas, probably, furnishes the purest flame which can be exhibited; for the flames of bodies which emit much light, derive that power from solid matter which is intensely ignited and diffused through them, and which in ordinary flames, as of gas, tallow, wax, oil, &c. consists of finely-divided charcoal.—*Brande.*

Dr. Ure, speaking of "the nature of flame, and of the relation between the light and heat which compose it," says, "The flame of combustible bodies may, in all cases, be considered as the combustion of an *explosive mixture* of inflammable gas or vapour with air. It cannot be regarded as a mere combustion at the surface of contact of the inflammable matter. This fact is proved by holding a taper, or a piece of burning phosphorus within a flame made by the combustion of alcohol. The flame of the taper, or of the phosphorus, will appear in the centre of the other flame, proving that there is oxygen even in its interior part.

Why does spirit of wine sometimes burn with various coloured flames?

Because of its admixture with different substances. Thus, from borax it acquires a *greenish yellow* tint; nitre, and the soluble salts of baryta, cause it to burn *yellow*, and those of strontia give it a beautiful rose colour; copper salts impart a fine *green.*

Dr. Ure, in his valuable *Dictionary of Chemistry*, (edit. 1830) gives the following recipe for the beautiful *red fire* now so effectively used to aid stage effect at the theatres:—40 parts dry nitrate of strontia, 13 parts finely powdered sulphur, 5 parts chlorate of potash, (hyper-oxymuriate) and 4 parts sulphuret of antimony.

Powder the two latter separately in a mortar, and then mix them on paper; after which add them to the other ingredients, previously powdered and mixed. No other kind of mixture than rubbing together on paper is required. Sometimes, a little realgar is added to the sulphuret of antimony; and frequently, when the fire burns dim and badly, a very small quantity of finely powdered charcoal, or lamp-black, will make it perfect.

Why is working in coal mines sometimes fatal to miners?

Because of the carburetted hydrogen gas, or damp, and noxious exhalations, during the working of the coals, from fissures or cracks in the beds; when this has accumulated so as to form one-thirteenth of the atmosphere of the mine, it becomes explosive by a lighted candle or any kind of flame. By miners, this gas is called *fire-damp*, to distinguish it from carbonic acid gas, which they call *choke-damp*.

The late Mr. Spedding, having observed that the explosive damp could only be kindled by flame, and was not liable to be set on fire by red-hot iron, nor by the sparks produced by the collision of flint and steel, invented a machine, in which, while a steel wheel was turned round with very rapid motion, flints were applied to it, and by the abundance of fiery sparks emitted, the miners were enabled to carry on their work in places where the flame of a lamp or candle would occasion dreadful explosions.

Why is the safety-lamp so called?

Because it consists of a lamp surrounded by a wire-gauze, which, by confining the flame from the fire-damp, without intercepting the light, enables the miners to work in safety; and which, in gratitude to its illustrious inventor, Sir H. Davy, is, in mining districts called *the Davy*.

Why does the wire-gauze prevent explosion?

Because the meshes of the gauze are of such a size that a flame of the gas attempting to pass through it, is so cooled by the heat-absorbing and heat-conducting power of the metal, as to be extinguished; or, in fewer words, the temperature of the flame is so much lowered as to be insufficient to ignite the inflammable mixture on the outside. This is shown by bringing down a piece of fine brass or iron wire-gauze upon the flame of a candle; or, what answers better, upon an inflamed jet of coal gas, it will, as it were, cut the flame in half. That the cooled gaseous matter passes through, may be shown by again lighting it upon the upper surface.

Mr. Brande further illustrates this principle, by supposing the flame of a common lamp to be everywhere properly surrounded with wire-gauze, and in that state immersed in an explosive gaseous mixture, (like the fire-damp) it will be inadequate to its inflammation; that part only being burned which is *within* the cage; communication to the inflammable air *without* being prevented by the cooling power of the metallic tissue; so that, by such a lamp, the explosive mixture will be consumed, but cannot be exploded.

The apertures in the gauze should not be more than one-twentieth of an inch square; in the working model which Sir Humphry Davy sent to the mines, there were 748 apertures in the square inch.

The above is the explanation of the principle, by, and from the reasonings of, the ingenious inventor himself.—Some facts known to Signor G. Libri, of Florence, were, however, at variance with this hypothesis, and he found, upon trial, that when single rods were made to approach a flame, the latter was always inflected on all sides from the rod, as if repelled by it; and that this effect was independent of the conducting power of the rod, whether good or bad. The amount of inflection or repulsion was directly as the mass, and inversely as the distance from the flame. It was not diminished by increasing the temperature of the rod even to such a degree as to render it scarcely possible for it to abstract any of the caloric. In fact, when two flames are made to approach each other there is a mutual repulsion, although their proximity increases the temperature, instead of diminishing it. From these principles, Signor L. says, the theory of the safety lamp is easily deduced. A metallic wire exerting, according to its diameter and its own nature, a constant repulsion upon flame, it is evident that two parallel wires so near each other as not to exceed the distance of twice the radius of the sphere of repulsion, will not permit a flame to insinuate itself between them, unless it be impelled by a force superior to the intensity of repulsion. If to these two wires others be added, a tissue is formed impenetrable to flame, especially when the conducting power of the wires adds its influence to that of the repulsion. He conceives that, from the views above stated, the number of cross or horizontal wires in Davy's lamps are unnecessarily large; and that by rejecting all of these excepting a number sufficient to secure the firmness of the tissue, the lamp would afford as great a security as at present, and, at the same time, diffuse a much greater light—this opinion he has verified by actual experiment.

Again, a Mr. Dillon, an ingenious writer on practical science, maintains, in opposition to Sir Humphrey Davy, that the Davy lamp acts by its heat and rarefaction, not from the flame being cooled by the wire-gauze covering. He shows, by a simple experiment, that the Davy lamp is not safe in a current of hydrogen, or carburetted hydrogen gas, which, if steadily directed on the flame of the lamp from a bladder and stop-cock, *by cooling the wire-gauze*, brings the flame of the lamp through the gauze to the mouth of the stop-cock, even should there be six folds of gau intervening. He shows also, by immersing the lamp, when cold and newly-lighted, into a jar of dense hydrogen, or carburetted hydrogen gas, or an explosive mixture with atmospheric air, that explosion takes place inside and outside of the lamp; whereas, when the lamp has burnt sufficiently long to heat the wire-gauze, no explosion takes place on the outside of the lamp. These experiments appear incontrovertible in support of his theory, which is, "*that the wire-gauze is merely the rapid receiver and the retainer of heat, and that it is the caloric in its meshes which prevents the flame of the lamp from being fed by the oxygen of the atmosphere on the outside.*"

Mr. Dillon increases the heat of the lamp, and places on it a shield of talc to protect it from a current, and, upon his theory, the shafts or workings of iron and coal mines may be lighted with gas with perfect safety, protecting the flame with wire gauze and a circular shield of talc.

The explosions from fire-damp are truly terrific. Sir H. Davy says, "when this gas has accumulated in any part of the gallery or chamber of a mine, so as to be mixed, in certain proportions, with common air, the presence of a lighted candle, or lamp, causes it to explode, and to destroy, injure, or burn, whatever is exposed to its violence. The miners are either immediately killed by the explosion, and thrown, with the horses and machinery, through the shaft into the air, —the mine becoming, as it were, an enormous piece of artillery, from which they are projected—or, they are gradually suffocated, and undergo a more painful death, from the carbonic acid (*choke damp*) and nitrogen remaining in the mine after the explosion of the fire-damp; or what, though it appears the mildest, is perhaps the most severe fate,—they are burned or maimed, and often rendered incapable of labour, or of healthy enjoyment, for life."

A comparative statement has been made of the number of explosions in coal mines, and the deaths occasioned by them, during the ten years which preceded, and the ten years which succeeded, the introduction of the Davy-lamp; from which it appears that

From 1805 to 1816 there were	9 Explos.	284 Deaths.
1817 1828 - -	19	360
Excess since the introduction of the Davy	10	76

This excess is accounted for by the workmen relying so much on *the Davy*, that, under its protection, they now work in places where they would not have formerly ventured to take a light. Inattention to the state of the lamps doubtless contributes to the lamentable total.

Mr. Brande judiciously observes, that as their safety "entirely depends upon the perfect state of the wire-gauze, and upon the non-existence of any aperture or channel sufficiently large to admit of the passage of flame, they should, when in use in a coal mine, be inspected daily, to ensure their soundness in these respects. In gas-manufactories, spirit-warehouses, and in all cases where inflammable vapours or gases are likely to be generated, as in the examination of foul sewers and drains, it is obvious that these lamps are importantly applicable."

Why do firemen, by the protection of Aldini's incombustible cloth and wire-gauze, remain for two or three minutes completely enveloped in flames, without injury?

Because, perilous as their situation may appear, they are supplied in some way with pure air. M. Gay Lussac observes, that when a furnace is heated so as to flame and smoke, the air within is entirely deprived of oxygen; and therefore it is certain, that if the immediate action of the flames were guarded off by the wire-gauze, still it would be impossible to sustain respiration in the midst of them. There are several ways of accounting for the requisite supply of air; and one which M. Gay Lussac suggests appears the most probable:

viz. that the men are supplied by a current of fresh air from the space between the two garments. Besides this, we cannot suppose that their heads are constantly enveloped in the flames, and they, of course, find favourable moments for breathing; again, the power of suspending the breath is also an excellent resource, which every fireman ought by practice to acquire. The fireman has another difficulty to contend with, in the dense volumes of smoke, which prevent his breathing, blind his sight, and consequently retard his exertions. To obviate this, it has been proposed to furnish a supply of air from a portable reservoir; or by means of a flexible tube, rising from the feet to the mouth, through which the fresh air would naturally rise, as the heated air escaped above.—*Phil. Mag.* 1830.

Why does amàdou, or German tinder, readily inflame from flint and steel, or from the sudden condensation of air?

Because it consists of a vegetable substance found on old trees, boiled in water to extract its soluble parts, then dried and beat with a mallet, to loosen its texture; and lastly, impregnated with a solution of nitre. —*Ure.*

Why is a piece of paper lighted, by holding it in the air which rushes out of a common lamp-glass?

Because of the high temperature of the current of air above the flame, the condensation of which is by the chimney of the glass.

Why does heated platinum wire, if placed round the wick of a spirit-lamp, continue to give light and heat, though without flame?

Because of the vapour of the spirit; the heat never becoming sufficiently intense to produce its inflammation. This discovery, by Davy, ultimately gave rise to the formation of a lamp, which, containing alcohol, and prepared at the place of the wick with a piece of spongy platinum, or, as Dobereiner calls it, sub-oxide of platinum, or some other form of that metal, gradually converted the whole of the alcohol into acetic acid.

The lamp in this form has been used for a night-lamp: it gives light enough to see the time by a watch held close to it; and if more light be required, a piece of amàdou may be carefully inflamed at it, and then a light procured in the usual way. Mr. Batka proposes to use Eau de Cologne in place of common spirit of wine, and finds, that then the fragrance diffused is very grateful; being, in fact, occasioned by the actual formation of aromatic vinegar, during the whole time the lamp burns.

COMBUSTION.

Why are certain bodies combustible?

Because of an intense chemical action which takes place in them, and is connected with their electrical energies; "for, all bodies which powerfully act upon each other, are in the opposite electrical states of positive and negative; and the disengagement of heat and light, (which characterizes combustion) may depend upon the annihilation of those opposite states which happens whenever they combine."—*Brande.*

Sir H. Davy has asserted, "that in any case combustion is merely the appearance produced, when substances, which have perhaps still stronger attraction for each other than quick-lime and water, are combining chemically, so as to become heated, at least, to the degree of incandescence. During the phenomenon, there is not, as was formerly supposed, something altogether consumed and destroyed, or something called *plogiston* escaping; the substances concerned are but assuming a new form and arrangement.

Of the substances called combustible, there are only a few which will begin to unite or burn at the common temperature of our globe, the others requiring to be at some higher and peculiar temperature. Thus, phosphorus begins to burn at 150°, sulphur at 550°, charcoal at 750°, hydrogen at 800°; it appearing, that up to these temperatures, the attraction of the atoms among themselves is sufficient to resist the other attraction, or that of oxygen. But when the combustion once begins, the temperature, from the effect of the combustion itself, rises instantly, much beyond the degree necessary for the commencement of the process. Oxygen and hydrogen, which begin to burn or combine at 800°, produce a flame of as intense heat as human art can excite.—*Arnott.*

Why are other bodies, as a stone, or brick, termed incombustible?

Because, when heated, they undergo no change except an augmentation of temperature, and when left to themselves, they soon cool again, and become as at first. But, with combustible bodies, the case is very different. When heated to a certain degree in the open air, they suddenly become much hotter of themselves, and continue for a considerable time intensely hot, sending out a copious stream of coloric and light to the surrounding bodies. This emission, after a certain period, begins to diminish, and at last ceases altogether. The combustible body has now undergone a complete change,—it is converted into a substance possessing very different properties, and no longer capable of combustion.—*Thomson.*

Again, of substances burning in air, those which are originally aëriform, as coal gas, or which, on being heated are vapourised or rendered aëriform, before their union with the oxygen of the atmosphere takes place, as oil or wax, assume the appearance of flame; viz. the aëriform particles usually invisible, are raised to the incandescent temperature; but when the substance combining with the oxygen remains solid, while its particles are gradually lifted away by the oxygen acting only at the surface of their mass, it appears during the whole time only as a red-hot stone.

The latter is the case of charcoal, coke, Welch stone, coal, &c. while in the case of wood, common coal, &c. a greater or less portion of the inflammable matter, is, by the heat of the combustion, converted into vapour, and produces the beautiful appearance of flame.

Men, now grown familiar with prodigies, have almost ceased to be moved by them; but few persons can resist a feeling of wonder and admiration when chemistry, in its progress of discovery, every now and then calls forth the hidden spirit of combustion in some new or less familiar guise;—for instance, when a piece of iron wire, lighted as a taper in oxygen gas, burns with such resplendent brilliancy; or, when phosphorus, similarly placed, throws around its overpowering flood of flame; or, when small portions of the metal called potassium, being cast upon the surface of water, become as beads of most intense light, running about there, and crossing as in a merry dance;—or, lastly, when flames produced from particular substances are seen rising deep-tinged with most vivid and beautiful colours.—*Arnott.*

Why does a common fire smoke?

Because of the vapour of the water from the moisture of the fuel; and the carburetted hydrogen and bituminous substances, formed during combustion by the union of the hydrogen of the combustible with the oxygen of the atmosphere.

Why does a draught support a fire?

Because it flows towards the fire-place, to occupy the vacancy left by the air that has undergone decomposition, and which, in its turn, becomes decomposed also. Hence, a supply of caloric is furnished without intermission, till the whole of the combustible is saturated with oxygen.—*Parkes.*

Why do not coals, wood, &c. being combustibles, take fire on exposure to the air?

Because all such bodies require to have a certain preparatory temperature before beginning to combine with the oxygen of the atmosphere.

Why is heat produced by combustion?

Because of the decomposition of the oxygen gas of the atmosphere; for, as the oxygen combines with the combustible body, it disengages the caloric which is held when in the state of a gaseous substance. Or, to speak with more precision, the act of combustion effects a real analysis of atmospheric air; for while the oxygen combines with the combustible, the caloric, in the form of sensible heat, is thrown off in every direction.—*Parkes.*

Why do lamps with many wicks, placed near each other, give much more light than the same number of wicks would, if placed in separate lamps?

Because the light given out by a combustible body is in proportion to the elevation of temperature; and in this case the many wicks communicate heat to each other.

Why is oxygen a powerful supporter of combustion?

Because it is more abundantly diffused throughout nature than any of the other elementary bodies; it forms eight-ninths of the weight of water, about one-fifth of the weight of the atmosphere, and a relative proportion of the earthy and mineral bodies which form the solid matter of the globe. Hence, it is present everywhere, and ready to unite itself with any matter exposed to it at the necessary temperature.

Why is oxygen gas called vital air?

Because it is a powerful supporter of respiration. Thus, a small animal confined in oxygen gas, lives thrice as long as when confined in the same bulk of common air; but we are not thence to conclude that it is fit for the support of life; on the contrary, an animal made to breathe oxygen for any length of time, falls a sacrifice to excess of arterial action; and after death, the blood in the veins is found as florid as that in the arteries.—*Brande.*

Why is it considered that oxygen unites with the combustible body in the act of burning?

Because, if a substance be burnt in a sufficient quantity of oxygen gas, in a close vessel, and the product preserved, the whole will be found to be increased in weight exactly in proportion to the oxygen gas consumed, and the combustible body will then have become incombustible.—*Parkes.*

Fourcroy observes, "this view of combustion authorises us to divide almost all the productions of nature into two grand classes; one of combustible bodies, the other of bodies already *burnt*; in the masses and action of the former we discern the causes of inflammable meteors, the perpetual alteration of the surface of the earth, volcanoes, &c. In the existence of the latter we perceive the source of the number and diversity of acids, saline compounds, oxides, and metallic salts, which vary in a thousand ways the appearance of ores, &c."

Why is not a goblet, when pushed into water with the mouth downwards, filled with water?

Because the air in the goblet resists the entrance of the water; and, if the goblet be inverted over a floating lighted taper, this will continue to float under it, and to burn in the contained air, however deep in the water it be carried, exhibiting the curious phenomenon of a light below water, and itself an emblem of the living inmate of a diving bell, which is merely a larger goblet, with a man instead of a candle.—*Arnott.*

Why is the name fuel given only to the substances which combine with oxygen, and not to the oxygen itself?

Because, probably, the former being solid or liquid, and therefore more obvious to sense, were known as producers of combustion long before the existence of the aëriform ingredient was even suspected.—*Arnott.*

Why does a candle or lamp smoke?

Because the heat produced by it is not sufficient to effect the total combustion of the carbon, which rises in its flame.—*Arnott.*

SPONTANEOUS COMBUSTION.

Why are human bodies sometimes destroyed by spontaneous combustion?

Because of a new arrangement of the muscles, tendons, viscera, &c.; or new products originating from their degeneration.

Numerous instances of this mortal catastrophe are recorded. M. Julia de Fontenelle, in a paper lately read to the Academy of Sciences at Paris, describes fifteen cases, from the details of which the following general results are obtained:—

1. Generally those who have died by spontaneous combustion, have indulged in excess of spirituous liquors. 2. The combustion is almost always general, but in some cases it may be partial. 3. It is rare amongst men; and the women have in almost every case been aged. 4. The body and the viscera have always been burnt, whilst the feet, hands, and crown of the head have almost always been saved. 5. Although it is known by experience that a very large quantity of wood is requisite to burn a corpse, this particular kind of incineration occurs without inflaming the most combustible substances of an ordinary kind near it. 6. It has not been shown, in any case, that the presence of fire is necessary to commence this kind of combustion. 7. Water, instead of extinguishing the flame, appears to give it more activity; and when the flame has disappeared, the combustion proceeds within. 8. They occur more frequently in winter than in summer. 9. The cure of general combustions has never been effected; but sometimes that of partial ones. 10. Those seized with combustion experience a sensation of strong internal heat. 11. It

is suddenly developed, and consumes the body in a few hours. 12. Those parts not reached by the fire, are affected by gangrene. 13. A putrid degeneration ensues, which causes gangrene. 14. The residue of this combustion is composed of greasy cinders, and an unctuous matter.

Professor Jameson observes, in substance, upon this interesting question: "we are of opinion that, in some subjects, and chiefly in women, there exists a general condition of the body, which, conjoined with the extreme debility occasioned by age, a life of little activity, and the abuse of spirituous liquors, may give rise to a spontaneous combustion. But we are far from considering as the material cause of this combustion, either alcohol, or hydrogen, or a superabundance of fat. If alcohol plays a prominent part in this combustion, it is by contributing to its production: that is to say, it produces, along with the other causes mentioned, the degeneration of which we have spoken, which gives rise to new products of a highly combustible nature, the reaction of which determines the combustion of the body."

A curious case of the combustion of both hands only, in which the patient recovered, is related in the *Medical Journal*, 1830.

CHARCOAL.

Why do various woods afford different quantities of charcoal?

Because of their different durability; those most abundant in charcoal and earthy matter are the most permanent; while those that contain the largest portion of the gaseous elements are the most perishable. Among British trees, the chestnut and oak are the most permanent, and the chestnut affords rather more charcoal than the oak.

The beams of the theatre at Herculaneum were converted into charcoal by the lava which overflowed that city; and during the lapse of seventeen hundred years the charcoal has remained as entire as if it had been formed but yesterday; and it will probably continue so to the end of the world. The incorruptibility of charcoal was known in the most ancient times: the famous temple at Ephesus was built upon wooden piles, which have been charred on the outside, to preserve them.—*Watson's Chemical Essays.*

A new process for manufacturing charcoal, is to fill all the interstices in the heap of wood to be charred, with powdered charcoal; the product is equal in quality. The effect is produced by preventing much of the access of air which occurs in the ordinary method. The volume of charcoal is increased a tenth, and its weight a tenth.—*Bullétin Universel*, 1830.

Professor Silliman, in his Journal, (1830) says, that in the United States, wood is charred in brick-kilns, with openings at the top and sides, under regulation; and the charcoal thus obtained is exceedingly good, and more abundant than by the old mode of burning.

Wood has also been charred at low temperatures. Thus, on making extracts, in wooden vessels, with steam of very moderate pressure, all the apparent effects of burning may be produced; but the carbonization of the wood is not so complete as by flame. This fact is practically illustrated in the *Philosophical Magazine*, 1830.

The application of charcoal to various purposes of domestic economy has been already noticed in Part I of the present work.*

Why does heated charcoal produce combustion?

Because the mutual cohesion of its particles is so weakened, that is, the particles are so repelled and separated from each other, that their attraction for the oxygen in the air around is allowed to operate, and they combine with that oxygen, so as to produce the above phenomenon.

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* See DOMESTIC SCIENCE, p. 6.

Why does charcoal increase in weight on exposure to the air after burning?

Because it is a very hygrometric substance, and therefore absorbs air and moisture in considerable quantity.—*Brande.*

Why do sailors at sea throw pieces of burnt biscuit in bad water?

Because it serves as charcoal in destroying the putrid flavour of the water, and rendering it comparatively fresh.

Why does fresh charred wood, or charcoal, improve the flavour of spirits?

Because it destroys the essential oil, or empyreumatic flavour which the spirit may have contracted in distillation.

GUNPOWDER.

Why do mixed nitre, sulphur, and charcoal, or gunpowder, explode with heat; whereas, while cold, they may be mixed together most intimately without any change?

Because, by the change of temperature, and the consequently altered relative attractions of the different substances, a new chemical arrangement of them takes place with the intense combustion and expansion which constitute the explosion.

The proportions of the ingredients of gunpowder vary. The following are those usually employed—

	Common Powder.	Shooting Powder.	Shooting Powder.	Miners Powder.
Saltpetre	75.0	78	76	65
Charcoal	12.5	12	15	15
Sulphur	12.5	10	9	20

The latter contains the smallest quantity of saltpetre, as it requires less quickness or strength. The ingredients are *perfectly* mixed, moistened, beaten into a cake, which is afterwards broken up, granulated, dried, and for the finest powder, polished by attrition. —*Brande.*

Why is iron excluded from powder works?

Because it is liable to cause sparks by a blow. Brass and copper have been recommended in its place; but Col. Aubert has remarked that brass can inflame powder, and has made experiments on the subject before a committee, the result of which is as follows:—Inflammation of the powder takes place when the blow is given by iron against iron; iron against brass; brass against brass: iron against marble; lead against lead, or against wood, when the blow is produced by a leaden ball shot from a fire-arm. As yet, powder has not been inflamed by the blow of an iron hammer against lead or wood.—*Bulletin Universel.*

Why is steam likely to supersede gunpowder in the discharge of artillery?

Because the elastic force of high-pressure steam having much greater range than that of gunpowder, is infinitely better calculated for projectiles, independently of any saving of expense. It is estimated by Mr. Perkins, that the projectile force of steam is ten times greater than that of gunpowder, in throwing a ball to a given distance.

Why do "Prometheans" suddenly inflame on pressure?

Because they consist of small glass bulbs, filled with concentrated sulphuric acid, hermetically sealed, and surrounded with a mixture of inflammable materials, amongst which the chlorate of potash forms one; and the whole being again inclosed or surrounded with paper, also rendered still more inflammable by means of resinous matters. Upon pinching the end containing the glass bulb, between the jaws of a pair of pliers, the bulb breaks, and the sulphuric acid instantly kindles the surrounding materials.

VOLCANIC FIRE.

Why are volcanoes produced?

Because, according to the most recently observed phenomena, they "depend upon the oxidation of the metals of the earths upon an extensive scale, in immense subterranean cavities, to which water or atmospheric air may occasionally have access. The subterranean thunder heard at great distances under Vesuvius, prior to an eruption, indicates the vast extent of these cavities; and the existence of a subterranean communication between the Solfatarra and Vesuvius, is established by the fact that whenever the latter is in an active state, the former is comparatively tranquil. In confirmation of these views, the author remarks, that almost all the volcanoes of considerable magnitude in the old world, are in the vicinity of the sea; and in those where the sea is more distant, as in the volcanoes of South America, the water may be supplied from great subterranean lakes; for Humboldt states that some of them throw up quantities of fish."

The phenomena observed by the author afford a sufficient refutation of all the ancient hypotheses, in which volcanic fires were ascribed to such chemical causes as the combustion of mineral coal, or the action of sulphur upon iron; and are perfectly consistent. The author acknowledges, however, that the hypothesis of the nucleus of the globe being composed of matter liquified by heat, offers a still more simple solution of the phenomena of volcanic fires.—*Sir H. Davy, Philosophical Transactions.*

On these phenomena, Baron Humboldt says, "Observations made in all countries, in mines and caves, prove that, even at a small depth, the earth's heat is much superior to the temperature of the surrounding atmosphere. A fact so remarkable, and elicited from observations made in almost every part of the globe, connects itself with what we learn of the phenomena of volcanoes. La Place has even attempted to determine the depth at which the earth may be considered as a melted mass. Whatever doubts may be entertained, notwithstanding the respect due to so great a name, as to the numerical accuracy of such a calculation, it is not the less probable, that all volcanic phenomena arise from a single cause, which is the communication constant or interrupted, that exists between the interior of our planet and the external atmosphere. Elastic vapours, by their pressure, raise through deep crevices the substances which are in a state of fusion, and which are oxidized. Volcanoes are, so to speak, entermittent springs of earthy matters. The fluid mixtures of metals, alkalies and earths, which condense into currents of lava, flow gently and slowly, when, on being raised up, they once find an issue.

Why does water appear necessary to produce volcanic fire?

Because the most active volcanoes are in the immediate vicinity of the sea; some are actually beneath the sea; and only extinct volcanoes are found far inland.

Why are earthquakes and volcanoes supposed to be of the same origin?

Because of the frequency of earthquakes in volcanic countries; and when they occur in non-volcanic countries, remote from volcanic fires, or their occurrence, the coincidence of distant volcanic eruptions. It is a remarkable circumstance, also, that the shocks of earthquakes are most severe in non-volcanic countries, such as Lisbon and the Caraccas.—*Notes in Science.*

Why do hot springs occur in the very vicinity of all active volcanoes?

Because, probably, such waters owe their temperature to their passage through channels heated by volcanic fire.—*Berzelius.*

Why do volcanoes throw out pumice stone?

Because the light-coloured, or whitish porous lavas, becoming fibrous, pass into the above light spongy stone.

Why is pumice stone sometimes seen floating on the sea?

Because it is produced by submarine volcanoes, that break out at such vast depths under the ocean, that none of their products reach the surface, except such as are lighter than water. Pumice has been seen floating upon the sea over a space of three hundred miles, at a great distance from any volcano.

Why is puzzolano used for building in water?

Because, when mixed with lime, it speedily fixes itself, and the water does not soften it, for it becomes continually harder and harder. The lime found abundantly at Dorking, in Surrey, has a similar property of hardening under water.

END OF PART V.

KNOWLEDGE FOR THE PEOPLE:

OR THE

PLAIN WHY AND BECAUSE.

PART XII.—POPULAR CHEMISTRY.

POPULAR CHEMISTRY.

Continued from Part V.

THE DIAMOND.

Why is carbon known by the names of diamond and charcoal?

Because the two latter substances, although so different, and almost opposite, in physical characters, are, according to unexceptionable experiments, almost chemically the same.

That diamond is simple carbon, is shown by the following experiment. M. Morveau exposed a diamond to intense heat, shut up in a small cavity in a piece of tough iron. When he opened the cavity, he found the diamond entirely gone, and the iron around it converted into steel. This shows that it is *pure* carbon, which combines with iron to form steel, and not charcoal, which is generally an oxide of carbon. The peculiar hardness of steel is to be ascribed to its union with a portion of pure carbon, or diamond. It is no uncommon thing for jewellers to expose such diamonds as are foul, to a strong heat, imbedded in charcoal, to render them clear; but, in this process, great care is taken to have a sufficient quantity of charcoal, to exclude the atmospheric air: otherwise, the intense heat would produce combustion.—*Parkes*

Why is charcoal more inflammable than the diamond?

Because of the looseness of its texture, and the hydrogen it contains. The latter is indeed the only chemical difference perceptible between diamond and the purest charcoal: but Dr. Ure asks, "can a quantity of an element, (hydrogen) less, in some cases, than 1-50,000th part of the weight of the substance, occasion so great a difference in physical and chemical characters?" In the *Philosophical Transactions* for 1797, is related Mr. Smithson Tennant's process for proving the identity of these two substances: he says, "It will appear, from experiments, that the diamond consists entirely of charcoal, differing from the usual state of that substance only by its crystallized form,"—and Dr. Ure thinks this opinion to be correct.

The identity of charcoal and diamond is further illustrated in the following experiment. Sir Humphry Davy exposed charcoal to intense ignition, *in vacuo*, and in condensed azote, by means of Mr. Children's magnificent battery, when it slowly volatilized, and gave out a little hydrogen. The remaining was always much harder than before, and in one case, so hard as to scratch glass, while its lustre was increased. This fine experiment may be regarded as a near approach to the *production of diamond*; and we believe that similar experiments of French chemists have been equally successful.

Why did Newton infer that the diamond was inflammable?

Because of the circumstance, that inflammable substances refract light in a greater ratio than that of their densities. We readily acquiesce in Mr. Parkes's note: "It is wonderful that Newton, who had no chemical means of examining the diamond, should have conceived the idea of its inflammable nature."

It is not evident to whom the combustibility of the diamond first occurred; but, in the year 1694, the

Florentine Academicians proved its destructibility by heat, by means of a burning lens. The products of its combustion were first examined by Lavoisier, in 1772, and subsequently, with more precision, by Guyton Morveau, in 1785. Mr. Tennant's experiments, just referred to, demonstrated the important fact, that when equal weights of diamond and pure charcoal were submitted to the action of red-hot nitre, the results, in both cases, were the same; and, in 1807, the combustion of the diamond in pure oxygen, was found by Messrs. Allen and Pepys, to be attended with precisely the same results as the combustion of pure charcoal. Hence, observes Brande, the inevitable inference, that charcoal and the diamond are similar substances in their chemical nature, differing only in mechanical texture.

The combustion of the diamond may be most conveniently and perfectly effected, by placing it upon a platinum capsule, in a jar of pure oxygen, inverted over mercury, and throwing upon it the focus of a burning lens. Sir Humphry Davy, when at Florence, in 1814, (*Phil. Trans.*) used for this purpose the same lens which was employed in the first trials on the action of solar heat on the diamond, instituted by Cosmo III, Grand Duke of Tuscany; he found, that when strongly ignited by the lens in a thin capsule of platinum, perforated with many orifices, so as to admit a free circulation of air, the diamond continued to burn in the oxygen, after being withdrawn from the focus, with so brilliant a light as to be visible in the brightest sunshine, and with very intense heat. The results of these experiments demonstrate, that diamond affords no other substance by its combustion than pure carbonic acid gas; and that the process is merely a solution of diamond in oxygen, without any change in the volume of the gas. It likewise appears, that, in the combustion of the different kinds of charcoal, water is produced; and that, from the diminution of the volume of the oxygen, there is every reason to believe, that the water is formed by the combustion of the hydrogen existing in strongly ignited charcoal.

Why is pure carbon, or diamond, so scarce, while its compounds, in different states, are so abundantly dispersed?

Because, (observes an eminent chemist*) "the wonder consists only in the opposition between facts and our opinions; it disappears in proportion as we discover and appropriate the powers of nature to produce the same effects. To dispel the astonishment of those who might consider this a ground of distrust, I shall remind them that aluminous earth is likewise one of the commonest substances, though the adamantine spar, no less rare than the diamond, is nevertheless alumina; that iron exists every where, under every form, except in the state of purity; and that the existence of native iron is still doubtful." Since the preceding observations were written, native iron is stated to have been found in Canaan, in the United States of America.

Diamonds are usually found in an ochreous, yellow earth, under rocks of grit-stone; they are likewise found detached, in torrents, which have carried them from their beds. They have no brilliancy when dug out of the earth, but are covered with an earthy crust. The diamond was first discovered in Asia, in the provinces of Golconda and Visapour, in Bengal, and in the island of Borneo. About the year 1720, diamonds were first found in Brazil; and a minute account of their discovery will be found in a volume of travels in that country, by the late Mr. Mawe, one of the most distinguished mineralogists of his time.

The primitive form of the diamond is the regular octoëdron, each triangular facet of which is sometimes replaced by six secondary triangles, bounded by curved lines; so that the crystal becomes spheroidal, and presents forty-eight facets. Diamonds with twelve and twenty-four facets, are not uncommon.

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* Dr. John Thomson, notes on *Fourcroy*.

Why was it supposed that the diamond might contain oxygen?

Because of its high refractive power. Such was the idea of MM. Biot and Arrago. According to Biot, if the elements of which a substance is composed, be known, their proportions may be calculated with the greatest accuracy, from their refractive powers. Thus, he finds that the diamond cannot be pure carbon, but requires, at least, one-fourth of hydrogen, which has the greatest refractive power of any substance, to make its refraction commensurate to its density. Sir Humphry Davy, from the action of potassium on it, and its non-conduction of electricity, suggested, in his third Bakerian lecture, that a minute portion of oxygen might exist in it; and he threw out the idea, that it might be the carbonaceous principle, combined with some new, light, and subtle element, of the oxygenous and chlorine class.—*Ure.*

Why has the diamond so great lustre?

Because it reflects all the light falling on its posterior surface at an angle of incidence greater than 24° 13′. Artificial gems reflect half of this light.

The base of all artificial stones is a paste composed of silex, potash, borax, oxide of lead, and sometimes arsenic. The best silex is obtained from rock crystal, and the next best from white sand, or flint.

Why are diamonds used for the lenses of microscopes?

Because they show us the real object, without any sensible aberration, like that produced by glass lenses. This arises from the enormous refractive power possessed by the diamond, and the consequent increase of amplification, with very shallow curves. Again, the refraction of diamond is nearly three times that of glass; hence, in equal refractions, its dispersion will be only one-third of the latter.

We have elsewhere* noticed the cutting properties of the diamond. Dr. Wollaston, in the *Philosophical Transactions*, has clearly shown that it is only in the natural state that diamond can be depended upon to cut or divide panes of glass; and even then, a particular crystallization is absolutely necessary. The diamond has also been employed in ornamenting steel. Thus, Mr. John Barton, of the Royal Mint, has produced the most beautiful display of prismatic colours, by divisions, 2000 in an inch, the lines being made with a natural diamond. It would be impossible to convey the smallest idea of the exquisite beauty and play of colours that are produced by these means.

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* See PART X. *Arts and Manufactures*, p. 52.

Why is the sapphire used for the lenses of microscopes?

Because, after the diamond, it possesses a stronger refraction than any other substance, capable of giving a single image, while its dispersive power is very low. The faint blue tinge of the sapphire is not felt in thin small lenses formed of this substance, which thus comes next in order to diamond ones, and forms an excellent substitute for the use of those persons unable to afford the expense of the latter.

Why is the value of a brilliant-cut diamond esteemed equal to that of a similar rough diamond of twice the weight, exclusive of the cost of workmanship?

Because, by cutting and polishing, but especially by the former, so much is taken away, that the weight of the polished gem does not exceed half that of the rough stone. The art of cutting and polishing diamonds, though probably of remote antiquity in Asia, was first introduced into Europe by Louis Berghen, of Bruges, who accidentally discovered, that, by rubbing two diamonds together, a new facet was produced.

The weight, and therefore, the value, of diamonds, is estimated in *carats*, 150 of which are about equal to 1 oz. troy, or 480 grs. They are divided into halves, quarters, or carat grains, eighth, sixteenth, [illegible] irtysecond parts. The difference of value between one diamond and another, is, generally speaking, as the squares of their respective weights: thus, the value of three diamonds, of one, two, and three carats' weight, respectively, is as one, four, and nine. The average price of rough diamonds is estimated at 2*l.* per carat; and consequently, when wrought, the cost of the first carat, exclusive of workmanship, will be 8*l.*, which is the value of a rough diamond of two carats.

			£
A wrought diamond of	3 carats	is worth	72
————	4	————	126
————	5	————	200
————	10	————	800
————	20	————	3,200
————	30	————	7,200
————	40	————	12,800
————	50	————	20,000
————	60	————	28,800
————	100	————	80,000

This mode of valuation, however, only applies to small diamonds, in consequence of the difficulty of finding purchasers for the larger ones.

Why are diamonds called male and female?

Because a hard and soft stone are often united in the same gem; the hard stone being called by diamond cutters a *he*, and the soft one, a *she*.

Why is a diamond said to be of the first water?

Because it is perfectly transparent and pure. The snow-white diamond is most highly prized by the jeweller. Diamonds have, however, been found nearly of all colours: next to the colourless, in esteem, are those of a decided red, blue, or green tint. Black diamonds are extremely rare; those which are slightly brown, or tinged only with other colours, are least valuable.

The largest known diamond is probably that mentioned by Tavernier, in the possession of the Great Mogul. Its size is about that of half a hen's egg; is cut in the rose form, and when rough, is said to have weighed 900 carats. It was found in Golconda, about the year 1650. Among the crown jewels of Russia is a magnificent diamond, weighing 195 carats. It is the size of a small pigeon's egg, and was formerly the eye of a Brahminical idol, whence it was purloined by a French soldier; it passed through several hands, and was ultimately purchased by the Empress Catharine, for the sum of £90,000 in ready money, and an annuity of £4000. Perhaps the most perfect and beautiful diamond hitherto found, is a brilliant brought from India by an English gentleman, named Pitt, who sold it to the Regent Duke of Orleans, by whom it was placed among the crown jewels of France. It weighs rather more than 136 carats, and was purchased for £100,000. —*Brande.*

Diamonds, equal to those of Brazil, have also been recently found in the Ural chain of mountains in Russia.

PROPERTIES OF CARBON.

Why is carbon so important in the vegetable kingdom?

Because it is not only a component part, but it forms nearly the whole of the solid basis of all vegetables; and their infinite varieties may be attributed to the different modifications of carbon, as well as of the other principles which enter into their constitution.

Why are so many products of vegetation indebted to carbon for their produce?

Because carbon not only constitutes the base of the woody fibre, but is a component part of sugar, and of all kinds of wax, oils, gums, and resins; and of these again how infinite is the variety.—*Parkes.*

Why is carbon also important in the animal kingdom?

Because it enters into the composition of animal milk, and of animal oils and fat; it is also found in albumen, gelatine, fibrina, and in many of the animal secretions.

Why is carbonic acid gas so called?

Because it consists of carbon, which has so great an affinity to oxygen, that when assisted by heat, it will take it from both substances with which it may be combined; and in certain proportions, they form carbonic acid gas. The composition of carbonic acid has been proved by analysis, as it has been actually decomposed, and the charcoal or carbon exhibited entire.

Why was carbonic acid also called fixed air?

Because it was so intimately combined in chalk, lime-stone, magnesia, &c. It is to Dr. Black we owe the discovery of carbonic acid gas. Mr. Keir was the first who suspected it to be an acid; and Dr. Priestley afterwards announced that a portion of it was always found in atmospheric air.

Again, it is probably decomposed by the organs of plants, its base furnishing part, at least, of the carbon that is so abundant in the vegetable kingdom, and its oxygen contributing to replenish the atmosphere with that necessary support of life, which is continually diminished by the respiration of animals, and other cause.

Saussure found carbonic acid in air from the summit of Mont Blanc; and Humboldt discovered it in air brought from a height of many thousand feet, to which he had ascended in a balloon. Its production in the lungs is easily shown, by blowing the expired air through lime-water, by means of a small tube: it becomes milky, and soon deposits carbonate of lime.

During the past year, likewise, Saussure has communicated to the Physical and Natural History Society of Geneva, some interesting experiments, to determine the variations of carbonic acid in the atmosphere. He found, that, near Geneva, 16 metres above the level of the lake, 10,000 volumes of air contained 4.15 of carbonic acid, as the mean of 104 experiments, made day and night, and at all seasons of the year; the air being taken four feet above the ground. An increased quantity of rain appeared to diminish that of the carbonic acid, either by dissolving it, or causing the soil to do so. It was found, that during the night, the quantity of carbonic acid was greater than that of the day, in the proportion of 4.32 to 3.98; but if the wind were strong, then scarcely any difference occurred. The greater quantity of carbonic acid occurring in the night, is attributed to the want of decomposition, which arises from vegetation during the day; a result which favours the explanation of the above question. A short frost, which does not penetrate the earth to more than an inch, does not appear to cause any variation in the quantity of carbonic acid; but when the frost continues long, the dryness which it occasions, increases the proportion. It was also found, that the quantity of carbonic acid is greater during the day in a city than in the country, that the variations occasioned by the seasons are analogous, and that the quantity of carbonic acid increases more by the influence of night in the country than in the town. The air of the plains contains more carbonic acid than that of the mountains; which difference is explained by considering that the decomposition of the acid occurs principally where vegetation is most abundant, as it is in the plains, and that the gas is absorbed by the earth there, because it contains more rain-water.—*Abridged from La Bibliothèque Universelle.*

Why is a blue flame so often seen upon the surface of a charcoal fire?

Because the combustion of the carbonic oxide is formed in this way: the air entering at bottom, forms carbonic acid, which, passing through the red hot charcoal, becomes converted into carbonic oxide. Hence arises the danger of burning charcoal in ill ventilated chambers.

Why is carbonic acid frequently found at the bottom of mines, wells, &c.?

Because it is much heavier than atmospheric air.

Workmen ought never to venture into such places without previously letting down a lighted candle. If the candle burns, they may enter safely; if not, quicklime should be let down in buckets, and gradually sprinkled with water. As the lime slacks, it will absorb the carbonic acid gas, and the workmen may afterwards descend in safety.—*Parkes.*

In these cases, the carbonic acid issues from crevices in the earth, and is produced by unknown sources. Similar accidents happen to persons incautiously descending into brewers' vats, before they have been purified from this gas. We were told of three or four such cases at the brewhouse of Messrs. Barclay and Perkins, as we were *walking over* their stupendous store-vats a few years since.

The noxious properties of carbonic acid, or choke-damp, in mines, have already been noticed in connexion with the *Safety Lamp.* (*See p.* 54, *et seq.*)

Why do persons experience difficulty of breathing, giddiness, and faintness, in crowded and illuminated rooms, which are ill-ventilated?

Because of the excess of carbonic acid which is always produced by the respiration of animals. In like manner, some manufactories are very unhealthy; as all common combustibles, such as coal, wood, oil, wax, tallow, &c. contain carbon as one of their component parts; so the combustion of these bodies is always attended by the production of carbonic acid. It is not, therefore, surprising, that carbonic acid should be always present in the atmosphere. Indeed, the great wonder is, considering the abundance of its sources, that it does not accumulate to an injurious degree, as it certainly would, without one of those admirable and providential compensations which perpetually strike us among the laws of nature; by which it is provided, that the process of vegetation should remove the contamination produced by the animal part.

Carbonic oxide, when respired, is fatal to animal life. Sir Humphry Davy took three inspirations of it mixed with about one-fourth of common air; the effect was a temporary loss of sensation, which was succeeded by giddiness, sickness, acute pains in different parts of the body, and extreme debility. Some days elapsed before he entirely recovered. Since then, Mr. Witter of Dublin was struck down in an apoplectic condition by breathing this gas; but he was speedily restored by the inhalation of oxygen.

Why have workmen often lost their lives by sleeping too near limekilns?

Because carbonic acid gas is extricated from the kilns in great abundance.

This brings to our recollection an incident, which occurred a few years back at a limekiln adjoining the old Bristol road, and manifests how perfectly insensible the human frame may be to pain in peculiar circumstances. It is related by Mr. Leonard Knapp, in his interesting *Journal of a Naturalist*, and though not exclusively illustrative of the above question, we are induced to quote his narrative:—"A travelling man one winter's evening laid himself down upon the platform of a limekiln, placing his feet, probably numbed with cold, on the heap of stones newly put on to burn through the night. Sleep overcame him in this situation; the fire gradually rising and increasing, until it ignited the stones upon which his feet were placed. Lulled by the warmth, he still slept; and though the fire increased until it burned one foot, (which probably was extended over a vent-hole) and part of the leg, above the ancle, entirely off, consuming that part so effectually, that no fragment of it was ever discovered —the wretched man slept on! and in this state was found by the kiln-man in the morning. Insensible to any pain, and ignorant of his misfortune, he attempted to rise and pursue his journey, but missing his shoe, requested to have it found; and when he was raised, putting his burnt limb to the ground to support his body, the extremity of his leg-bone, the tibia, crumbled into fragments, having been calcined into lime. Still he expressed no sense of pain, and probably experienced none, from the gradual operation of the fire, and his own torpidity during the hours that his foot was consuming. This poor drover survived his misfortunes in the hospital about a fortnight; but the fire having extended to other parts of his body, recovery was hopeless."

Why are dogs killed by entering the 'Grotto del cano,' in Italy, while man enters with safety?

Because the floor of the grotto is lower than the door, and this hollow is always filled with fixed air, which can rise no higher than the threshold, but there flows out like water. It has been a common practice to drive dogs into this cavern, where they suffer a temporary death for the entertainment of the passengers; but a man walks in with safety, because his mouth is far above the surface of this deleterious air. The lake of Averno, which Virgil poetically describes as the entrance to the infernal regions, evolves so large a quantity of this gas, that birds, flying over it, drop with suffocation.—*Parkes.*

Why does carbonic acid gas fill the apparently empty space, or upper part of the vessels, in which vinous fermentation is going on?

Because of the great weight of the gas, which prevents its ascent. Dr. Ure observes, "a variety of striking experiments may be made in this stratum of elastic fluid. Lighted paper, or a candle dipped into it, is immediately extinguished; and the smoke remaining in the carbonic acid gas, renders its surface visible, which may be thrown into waves by agitation, like water. If a dish of water be immersed in this gas, and briskly agitated, it soon becomes impregnated, and obtains the pungent taste of Pyrmont water. In consequence of the weight of the carbonic acid gas, it may be lifted out in a pitcher, or bottle, which, if well corked, may be used to convey it to great distances; or it may be drawn out of a vessel by a cock, like a liquid. The effects produced by pouring this invisible fluid from one vessel to another, have a very singular appearance: if a candle or small animal be placed in a deep vessel, the former becomes extinct, and the latter expires, in a few seconds after the carbonic acid gas is poured upon them, though the eye is incapable of distinguishing any thing that is poured. If, however it be poured into a vessel full of air, in the sunshine, its density being so much greater than that of the air, renders it slightly visible, by the undulations and streaks it forms in the fluid, as it descends through it."

Carbonic acid has a peculiar, sharp taste, which may readily be perceived over the vats in which wine or beer, is fermenting, as also in sparkling Champagne, and the brisker kinds of cider. It consists in 100 parts, of oxygen 72.72, the other 27.28 being pure carbon. It not only destroys life, but the heart and muscles of animals killed by it, lose all their irritability, so as to be insensible to the stimulus of galvanism.

Butterflies and other insects, of which it is desired to preserve the colours unimpaired, may sometimes be conveniently suffocated by this gas.

Why has soda water a brisk, sharp taste?

Because it is water, which, by artificial pressure with forcing pumps, has been made to absorb two or three times its bulk of carbonic acid, according to its sharpness. When there is added a little potash or soda, it becomes aërated or carbonated alkaline water:—"a pleasant beverage," observes Dr. Ure, "and a not inactive remedy in several complaints, particularly dyspepsy, hiccup, and disorders of the kidney." The effervescent quality of many mineral waters is referable to the presence of this gas, and they are often imitated by condensing carbonic acid into water, either by a condensing pump, or by a Nooth's apparatus, consisting of three vessels connected, which the observant reader may have noticed in the shops of chemists. We have already mentioned the water of Pyrmont: Spa and Seltzer are also instances: the last particularly, is highly impregnated with this acid. These waters are so pleasant and salutary, that various imitations of them, made in this country, are sold under the names of single and double soda water. They are manufactured by several houses in London, equal in every respect to the natural waters imported from the continent. Seltzer water is, we know, frequently introduced at the dinner tables of the wealthy, in tall stone bottles, similar to those used for beer in France and the Netherlands, and formerly used for spruce-beer in this country.

The strength of soda water, or the quantity of carbonic acid gas which it contains, is not, however, its main excellence; it should also contain soda. We know a patentee of soda water who nearly lost his life by experimenting upon the strength of his apparatus, which once burst with tremendous violence; the copper of the vessel, though of considerable thickness, was riven or torn asunder: he showed one of its fragments to Sir Humphry Davy, who requested it for his laboratory.

Carbonic acid gas may be rendered liquid by great pressure, and Mr. Brunel has endeavoured to apply this liquid as a mechanical agent for the production of motive power.

Why are carbonates so called?

Because they are combinations of carbonic acid with the alkalies, metallic oxides, in earths, and in stones; particularly in chalk, limestone, and marble. Thus, a cubic inch of marble contains as much carbonic acid in combination, as would fill a four-gallon vessel when in the state of gas.—*Parkes.*

Why is plumbago improperly called black lead?

Because it consists of iron, and a certain proportion of carbon; and thus, there is no *lead* in its composition. Many other instances might be adduced, in which the names of substances have given false ideas of their nature and properties. Thus, white and green copperas contain no *copper*, but are formed, the one with zinc, the other with iron.

Why is plumbago much used for making crucibles and portable furnaces?

Because, like charcoal, it is indestructible by heat, unless with the presence of atmospheric air. It protects iron from rust, and is on that account rubbed on various ornamental cast-iron works, such as the fronts of grates, &c.

Why is cast-iron submitted to a long intense heat, to be converted into wrought iron?

Because by this means the carbon burns, and, uniting with the oxygen, both go off in the state of carbonic acid gas.

Why do pit-coals vary in quality?

Because of the different proportions of carbon and bitumen which they contain; but carbon is the chief ingredient in all.

Why are some coals called slaty?

Because they hold also from 10 to 40 per cent. of earth; and some coals likewise contain a considerable quantity of sulphuret of iron, known by the name of martial pyrites.

There are four species of coal very distinct from each other: viz. the graphite of Werner, or plumbago; the anthracolite; the jet, or pitch coal; and the common coal. One hundred parts of plumbago contain, according to Berthollet, about 90 per cent. of charcoal, and 10 of iron. Anthracolite, or anthracite, is distinguished from other coal by burning without flame, and is sometimes called stone coal: it is composed of 64 carbon, 33 silica, and 3 parts of iron. Jet occurs in Scotland, at Whitby, in Yorkshire, in Bavaria, and in France, near the Pyreneés. It is composed of 76 parts charcoal, 22 parts bitumen, and two parts earth. Common coal is composed of bitumen and charcoal, and varies according to the places where it is procured.

OXYGEN.

Why is oxygen so called?

Because it enters into the composition of a large majority of the acids, (from two Greek words, signifying the formation of acids) and was formerly supposed to be the general acidifying principle.

Sir Humphry Davy appositely observes, that the great chemical agent, oxygen, is at once necessary in all the processes of life, and all those of decay, in which nature, as it were, takes again to herself those instruments, organs, and powers, which had for awhile been borrowed, and employed for the purpose or the wants of the living principle.

Growing vegetables, exposed to the solar light, give out oxygen gas; as do leaves laid on water in similar situations, the green matter, that forms in water, and some other substances.

Why is lead, exposed to a strong heat, and free access of air, converted into a bright red substance, known as minium, or red lead?

Because the lead gives out the oxygen which it had previously attracted from the air at a lower temperature. The red precipitate of the druggists is similarly produced from quicksilver, which, in the operation, increases its weight about 8 per cent.

Oxygen gas may be obtained in its greatest purity from the salt called chlorate of potassa. After the discovery of this gas, it was adopted by Lavoisier as the universal supporter of combustion. The basis of the gas was supposed to unite to the combustible, and the heat and light which it before contained in the gaseous state, were said to be evolved in the form of flame. But in this case several requisites are not fulfilled; the light depends upon the combustible, and not upon the quantity of oxygen consumed; and there are very numerous instances of combustion, in which, oxygen, instead of being solidified, becomes gaseous during the operation: and, lastly, in others no oxygen is present. Combustion, therefore, cannot be regarded as dependent upon any peculiar principle or form of matter, but must be considered as a general result of intense chemical action. We quote this perspicuous theory of combustion from Mr. Brande; its dependence upon electricity has been already noticed, as well as several properties of oxygen, in connexion with the general subject of combustion. (*See pp.* 60 *to* 65.)

CHLORINE.

Why is chlorine so called?

Because its colour is green (from the Greek word for green).

Dr. Ure observes, "the introduction of this term, (chlorine) marks an era in chemical science. It originated from the masterly researches of Sir Humphry Davy, on the oxymuriatic gas of the French school; a substance, which, after resisting the most powerful means of decomposition which his sagacity could invent, or his ingenuity could apply, he declared to be, according to the true logic of chemistry, an elementary body, and not a compound of muriatic acid and oxygen, as was previously imagined, and as its name seemed to denote. He accordingly assigned to it the term chlorine, descriptive of its colour, a name now generally applied."

Why are chlorine and its aqueous solution used to prevent infection?

Because chlorine has the power of decomposing the noxious compounds which produce contagion, and resolving them into others, which are harmless. Even when combined with lime, in the substance usually known as bleaching powder, chlorine retains this antiseptic power. For the purposes of fumigation, chlorine, liberated from manganese and muriatic acid, or manganese salt and sulphuric acid, may be diffused through the atmosphere of the infected chambers, or the infected goods may be exposed to it. In the same way, the offensive odour of dead bodies may be mitigated by sprinkling them with solution of chlorine. Chloride of lime has also been successfully used in cases of burns; to destroy the stench of bilge-water in ships, and to correct the confined air in their holds; as well as to destroy the fire-damp in mines.

Why is bleaching powder always used in a liquid form?

Because it has the property of bleaching only when water is present. Thus, if a piece of dry litmus paper be introduced into a jar of dry chlorine, it will suffer no change; but if previously wetted, the colour will speedily disappear. The colours of printed calico may readily be discharged by the same means.

The addition of the water to the chloride of lime, (or bleaching powder) effects its partial composition:—one half of the chlorine leaves the lime, and dissolves in the water; and this is the bleaching liquid of the shops, which is sold at a high rate, although it cannot cost more than a farthing a gallon. Sometimes this fluid is applied immediately to the substance to be bleached, but sometimes a weak acid is added, to destroy the slight affinity of the chlorine for the lime, and you will see by this addition, how much the bleaching power of the fluid is increased. The manufactory of the chloride of lime is carried on on a large scale in the north of England, by passing chlorine into *leaden chambers*, containing hydrate of lime in fine powder.—*Brande.*

Scheele first remarked this bleaching property; Berthollet applied it to the art of bleaching in France; and from him Mr. Watt introduced its use into Great Britain.

BROMINE AND IODINE.

Why is Bromine so called?

Because of its origin from a Greek word signifying "a strong disagreeable odour." In like manner, *iodine* is named from a Greek word signifying "violet-coloured," which distinguishes its vapour.

Bromine and iodine have only very lately been discovered, and they belong to that class of substances, with whose use in the economy of nature we are at present totally unacquainted, and which have not yet been applied to any practical purpose: nevertheless, they are objects of the greatest interest to the chemist; and the study of their properties is particularly instructive, on account of the analogy which subsists between them and chlorine.

Bromine probably exists in sea-water, but its relative proportion must be exceedingly minute. One hundred pounds of sea-water, taken up at Trieste, afforded 5 grains of bromide of sodium=3.3 grains of bromine. Here the bromine is unaccompanied by any iodine; and the same appears to be the case with the waters of the Dead Sea. In the water of the Mediterranean, on the contrary, iodine is always found with bromine. It is most readily recognised by evaporating the water, so as to separate all its more ordinary crystallizable contents, reducing the remainder to a very small bulk, and dropping in a concentrated solution of chlorine. The appearance of a deep yellow tint announces bromine. Dr. Daubeny, Professor of chemistry at Oxford, has discovered iodine and bromine in several salt springs and mineral waters of this country; and the Professor conceives that his analyses will tend to throw some light on the connexion between the chemical constitution of mineral waters and their medicinal qualities. Bromine has also been obtained from the ashes of sea-weeds, and we shall presently have occasion to notice its connexion with the cause of the ocean's tint. Thus, it has been discovered, not only in the waters of the ocean, but in certain salt springs, in the ashes of marine plants, and, according to Mr. Brande, in those of some marine animals.

Bromine acts with energy on the animal functions. A drop, let fall into the beak of a bird, was sufficient to kill it. Iodine was accidentally discovered in 1812, by M. de Courtois, a manufacturer of salt-petre at Paris. In his processes for procuring soda from the ashes of sea-weeds, he found the metallic vessels much corroded, and in searching for the cause of the corrosion, he made this important discovery. But for this circumstance, merely accidental, one of the most curious of substances might have remained for ages unknown; since nature has not distributed it, either in a simple or compound state, through her different kingdoms, but has stored it up in what the Roman satirist considers as the most worthless of things—the vile sea-weed.—*Ure.*

Iodine has been successfully applied in cases of cancer and bronchocele.

HYDROGEN.

Why is hydrogen employed for filling air-balloons?

Because it is much lighter than the atmosphere; the principle upon which balloons are constructed being, that a solid rises in the atmosphere with any given force, when its weight is less than the weight of the air which it displaces by the amount of that force. Hydrogen is the lightest substance in nature at present known, being 14.4 less dense than common air, 16 times less dense than oxygen, and 14 times less dense than nitrogen. Pure hydrogen gas is not, however, necessary to fill balloons; and carburetted hydrogen gas, such as is used to light the streets, has been advantageously substituted.

Dr. Ure considers every cubic foot of gas included in a balloon, to have by itself a buoyancy of fully one ounce avoirdupoise in the atmosphere. Hence, a balloon of ten feet diameter will have an ascensional force of fully 524 oz. or 33 lbs. *minus* the weight of the 314 superficial feet of the varnished silk enveloping the gas; and one of 30 feet diameter, a buoyancy of fully 14,137 oz. or nearly 890 lbs. *minus* the weight of the 2,827 feet of envelope. The subject of balloons, generally, belongs to *Pneumatics*.

Hydrogen also forms a component of all vegetable and animal products, and is therefore abundantly diffused throughout nature. It may be respired for a short time, though it is instantly fatal to all small animals. M. Maunoir, after having breathed a quantity of pure hydrogen, found that his voice had become remarkably shrill. It is inflammable, and extinguishes flame. When pure, it burns quietly, with a lambent flame at the surface, in contact with air; but if mixed with thrice its volume of air, it burns rapidly, and with detonation.

THE BLOWPIPE.

Why is the gas blowpipe so important an instrument in chemical analysis, &c.?

Because it enables us to employ a mixture of oxygen and hydrogen gases, and thus to produce the most powerful heat yet known. This may be shown by preparing a bladder full of each of these airs, and forcing some out of each, into a common tube connected with both, and throwing a stream of the mixed gases on burning charcoal, or on any other substance in the act of combustion. These bladders should each be furnished with a small metallic pipe, and stop-cock, and the tube connecting with both should have a very small orifice, in order that a regular stream of the commixed gas may be thrown upon the burning substance. This is called the hydro-oxygen blowpipe, and its construction and use were illustrated by the late Dr. E. Clarke, in a series of beautiful experiments in the fusion and reduction of earths and metals, and their compounds. Mr. Hare of Philadelphia, also fused, by this apparatus, porcelain, common pottery, Wedgwood's ware, pipe and porcelain clay, fine brick, common brick, and compound bricks, with equal ease. M. Lampadius, on making use of the gas blowpipe, found the heat, which is produced by the combustion of oxygen, with carburetted hydrogen gas, procured from coal, to be more intense than that with pure hydrogen. Mr. Brande, however, thinks the above blowpipe always a dangerous instrument, and adds, "nearly as intense a temperature may be safely produced by propelling oxygen through the flame of a spirit lamp."

Why is the common blowpipe, or simple bent tube, less advantageous than that just described?

Because it is hurtful to the lungs, and cannot be used but with much inconvenience, from the necessity of keeping up a continued blast. To effect the latter, bellows have been added, but as portability is a great object, they are more objectionable than bladders, which occupy little room when empty, and may be quickly filled with air. Mr. K. T. Kemp, of Edinburgh, has, however, invented a blowpipe which is very portable, requires scarcely any exertion of the lungs, one expiration into it being sufficient to produce a continued blast for about two minutes—and occupies very little space. It is described and drawn in *Jameson's Journal* for 1829, and in the *Arcana of Science and Art* for 1830, *p.* 145.

WATER.

Why is hydrogen so called?

Because it is one of the elements of water (from the two Greek words signifying the formation of water).

Thus, when two volumes of pure hydrogen gas are mixed with one volume of pure oxygen gas, and the mixture inflamed in a proper apparatus by the electric spark, the gases totally disappear, and the interior of the vessel is covered with drops of pure water, equal in weight to that of the gases consumed. Again, if pure water be exposed to the action of voltaic electricity, it is resolved into two volumes of hydrogen, disengaged at the negative pole, and one volume of oxygen, disengaged at the positive pole; so that water is thus proved by synthesis, and by analysis, to consist of two volumes of hydrogen combined with one of oxygen. We quote this illustration from Mr. Brande, who adds, "the experiments illustrating the composition of water, and showing the proportions in which its elements are united, are amongst the most important in chemistry.

The readiest means of decomposing water is as follows:—take a gun-barrel, the breech of which has been removed, and fill it with iron wire coiled up. Place it across a common chafing-dish, and connect to one end of it a small glass retort, containing some water; and, to the other, a bent tube, opening under the shelf of a water-bath. Heat the barrel redhot by means of charcoal, and apply a lamp under the retort. The steam of water, in passing over the redhot iron, will be decomposed, the oxygen will unite with the iron, and the hydrogen may be collected in the form of gas. This is the most economical way of making hydrogen in large quantities. Those who have had an opportunity of visiting an iron foundery, may see this process continually going on; for when the melted metal is poured into the damp moulds, the water which they contain is decomposed, and the hydrogen which is given off is ignited; and generally, from its mixture with the air, produces a slight explosion. If this experiment be made very carefully, by placing the iron wire, previously weighed, in a glass, or very compact earthen tube, instead of the gun-barrel, the weight which the iron will have acquired, added to the weight of the volume of gas produced, will be found exactly to make up the weight of the water decomposed; and they will be to each in the proportion of eight to one.

Water was, till modern times, considered as an elementary or simple substance. In 1776, the celebrated Macquer made an experiment, by burning hydrogen gas in a bottle, without explosion, and holding a white china saucer over the flame. His intention appears to have been that of ascertaining whether any fuliginous smoke was produced; and he observes that the saucer remained perfectly clean and white, but was moistened with perceptible drops of a clear fluid, resembling water; and which, in fact, appeared to him to be nothing but pure water. In the following year, Buquet and Lavoisier experimented to discover what is produced by the combustion of hydrogen; but Dr. Priestley, in 1781, appears to have first fired hydrogen and oxygen gas in a closed glass vessel; the inside of which, though clean and dry before, became dewy. The inference respecting this was, that these airs, by combustion, deposited the moisture they contained. Mr. Watt, however, inferred from these experiments, that water is a compound of the burnt airs, which give out their latent heat by combustion. In the same year, Mr. Henry Cavendish was busied on the subject, which he illustrated by a valuable series of experiments. The composition of water was not known or admitted in France till the year 1783, when it was proved by MM. Lavoisier and de la Place. The grand experiment in France was, however, by Fourcroy, Vaquelin, and Séguin, and was begun on May 13, 1790, and finished on the 22nd of the same month. The combustion was kept up one hundred and eighty-five hours with little interruption, during which time the machine was not quitted for a moment. The experimenters alternately refreshed themselves when fatigued, by lying for a few hours on mattrasses in the laboratory. The total weight of hydrogen and oxygen employed, was 7,249.227; the weight of water obtained was 7,244 grains, or 12 oz. 4 gros. 45 gr.; the deficit being 4.227 gr. The water being examined, was found to be as pure as distilled water.

The composition of water is best demonstrated, by exploding two volumes of hydrogen, and one of oxygen, in the eudiometer. They disappear, and pure water results. From the most careful experiments, it appears that a cubic inch of water, at the temperature of 60°, weighs 252.52 gr., and consists of 28.06gr. of hydrogen, and 224.46 gr. of oxygen. The volume of the former gas is 1,325 cubic inches, and, of the latter, 662, making together 1,987 cubic inches; so that the condensation is nearly 2000 volumes in 1.

Why is water universally found throughout nature?

Because it possesses a large range of affinity for natural bodies, of which it is capable of dissolving a greater number than any other fluid. It is found not only throughout the earth in an uncombined state, with its particles in the different aggregates either of ice, water, or vapour, but in a permanent and chemical union with a vast number of substances, solid, fluid, and gaseous. The air of the atmosphere, and even that which is considered the driest, contains much water in solution. Many solid minerals, and crystallized neutral salts, contain water in their composition; some of the latter to more than half their weight.

Why is hard water often improper for dyeing?

Because it contains salts with an earthy basis, which precipitate upon the stuff during boiling, and thus prevent the access of the colouring particles. Some of the earthy salts are indeed used in dyeing, but to alter and heighten particular colours. Well water is preferred in dyeing red, and other colours that want astringency; as well as in the dyeing of stuffs of loose texture, as calico, fustian, and cotton.

Why has the common practice of lining wells with bricks been condemned?

Because bricks soften the hardest water, and give it an aluminous impregnation.—*Dr. Percival.*

Why is water often found impregnated with sulphuretted hydrogen gas?

Because of the spontaneous decomposition of pyrites, or sulphuret of iron, where the spring rises. Hence, sulphuretted hydrogen gas, which consists of sulphur held in solution by hydrogen-gas, imparts the medicinal value to many celebrated springs, and is found very plentifully in all those natural waters, which emit that peculiar and offensive odour somewhat similar to rotten eggs, or the scourings of a foul gun-barrel. At a medium temperature, water will absorb from two-thirds to three-fourths of its bulk of this gas, and even twice its bulk.

Of this property were the several wells in London, supposed to be impregnated with the *spiritus mundi*, and sold by the monks as a kind of spiritual nectar; the most celebrated of which was the Holy-well, near Shoreditch.

Why does this water soon become turbid?

Because the cohesion of the sulphur to the hydrogen is very weak. It soon deposits pure sulphur. Hence, the sulphureous pellicles that are found in the channels in which this water flows, or the lining of the casks and other vessels in which it is usually conveyed.

Why is the purest water that which falls from the atmosphere?

Because, having touched air alone, it can contain nothing but what it gains from the atmosphere, and it is thus distilled without the chance of those impurities which may exist in the vessels used in an artificial operation.—*Sir Humphry Davy.*

Why is rain-water collected in towns less pure than elsewhere?

Because it always acquires a small quantity of sulphate of lime, and carbonate of lime, obtained from the roof and plaister of the houses. Again, the atmosphere of a smoky town will give some impregnation to rain, as it passes through. Hippocrates states, that rain-water should always be boiled and strained when collected near large towns; a fact now well known to chemists.

Why is the purest water produced from snow that has fallen on glaciers, which are themselves formed from frozen snow?

Because congelation expels both salts and air from water, whether existing below, or formed in the atmosphere: and, in the high and uninhabited regions of glaciers, there can scarcely be any substances to contaminate: removed from animal and vegetable life, they are even above the mineral kingdom. Sir Humphry Davy considers this to be pure water: its colour, when it has any depth, or when a mass of it is seen through, is bright blue; and, according to its depth, it has more or less of this colour. Captain Parry states, that the water on the Polar ice has the same beautiful tint. The reader will find some new and interesting observations on the colour of water in *Salmonia.*

Why is water distilled?

Because its foreign impurities may be completely separated from it. Distilled water as commonly prepared, however, always affords minute traces of foreign matter, especially when subjected to voltaic decomposition, and can only be considered as *perfectly* pure, when re-distilled, at a low temperature, in silver vessels.

Why is distilled water the lightest of all waters?

Because it contains neither solid nor gaseous substances in solution. It is perfectly devoid of taste; is colourless and transparent, feels soft, and wets the fingers more readily than any other. The principal cases in which distilled water has been used as an article of drink, have been in those important trials of the practicability of producing it by condensing the steam of seawater, by means of a simple apparatus fitted to a ship's boiler. These have fully shown the ease with which a large quantity of fresh water may be procured at sea, and that of the purest kind.

Why did the old chemists believe in the conversion of water into earth by distillation?

Because they found that the water, though purified by repeated distillation, if evaporated to dryness, always left a small residuum. Magraff distilled water seventy-two times, with this result; but Lavoisier determined that this residuum was entirely owing to the abrasion of the glass vessels in which the process was carried on.

Why has it been important to ascertain with precision the weight of pure water?

Because it is the standard with which all other liquids and solids are compared; as the weights of aëriform fluids are with atmospheric air. Moreover, a recent act of Parliament declares, that the standard measure cf capacity shall be the gallon, containing 10 lbs. avoirdupoise weight, (7000 gr.=1 lb.) of distilled water, weighed in the air, at the temperature of 62° of Fahrenheit's thermometer; the barometer being at 30 inches. The capacity of this gallon is 277.274 cubic inches.

Hoffman thus sums up the properties of pure water: "It is the fittest drink for all ages and temperaments: and, of all the productions of nature or art, comes nearest to that universal remedy so much sought after by mankind, and never hitherto discovered."

Why does potash soften hard water?

Because it decomposes all the earthy salts which oppose the solution of soap, by causing the earth to precipitate, whilst the neutral alkaline salt which is left, does not injure the solvent power of water.

Why does alum clear foul water?

Because this salt is decomposed by the carbonate of lime in the water, and the alumina carries down all sensible impurities.

This appears to be, in fact, a species of filtration, the efficacy of which, as a remedy for the long-complained-of impurities of the water of the Thames, we have already noticed, in Part I of this work. That the Thames water may be so purified is proved by the fact, that upon being taken to sea in casks, and becoming putrid, when it is racked off, and exposed to the air, it gradually deposits a black slimy mud, becomes clear as crystal, and remarkably sweet and palatable.

It might be expected that the Thames, passing a large town, and thus receiving its impurities, should thereby acquire a foulness, perceptible to chemical examination for a considerable distance below the town; but the most accurate examinations prove that, where the stream is at all considerable, these impurities have no influence in permanently altering the quality of the water; and, as they are only suspended, that mere rest will restore the water to its original purity. By this filtering process, or depuration, as is proved by Dr. Bostock, in the *Philosophical Transactions* for 1829, part 2, the quantity of saline matter in the water was increased as much as fourfold. Thus, 10,000 gr. of the water left by evaporation a saline crust, and were found to contain the following salts:

	After exam.	Before exam.
Carbonate of lime	4.20 gr.	1.55 gr.
Sulphate of ditto	.66	.12
Muriate of soda Muriate of magnesia	2.74	.23
	7.60	1.90

Thus, although the water, by this depurating process, freed itself from the great quantity of organic matter which it contained, and acquired a state of apparent purity, which might render it sufficiently proper for many purposes, yet that the quantity of saline matter was increased as much as fourfold. The greatest proportionate increase is in the muriates, which are very nearly twelve times more in the purified water than in that of the Thames in its ordinary state. The carbonate of lime is between two and three times as abundant as before, and the sulphate of lime between five and six times. This water, also, examined in its foul state, gave very obvious indications of both sulphur and ammonia, neither of which could be detected after depuration.

This depurating process may be denominated a species of fermentation; *i. e.* an operation, where a substance, without any addition, undergoes a change in the arrangement of its component parts, and a new compound or compounds are produced. The newly formed compounds were, in this case, entirely gaseous, and, except a part of the carbonic acid, were discharged. The saline bodies, not being affected by this process, remained in solution, leaving the fluid free, indeed, from what are considered as impurities, yet so much loaded with earthy and neutral salts, as to be converted from a soft into a hard water. The source of the saline bodies may be supposed to be the organic substances, principally of an animal origin, which are so copiously deposited in the Thames: of these, the most abundant are the excrementitious matters, as well as the parts of various undecomposed animal bodies. The different species of the softer and more soluble animal compounds, act as the ferment, and are themselves destroyed, while the salts which were attached to them are left behind. It may be conceived, therefore, that the more foul is the water, the more complete will be the subsequent process of depuration: and we have hence an explanation of the popular opinion, that the Thames water is peculiarly valuable for sea stores, its extreme impurity inducing the fermentative process, and thus removing from it all those substances which can cause it to undergo any further alteration.

The great importance of filters need not be further insisted on. In Paris, such an apparatus is to be found in almost every house; yet the water of the Seine is of great purity, and even purer than any of the tributary streams which surround it. It does not contain more than five grains of solid matter in the pint.

Within these few months, a plan has been submitted to the Royal Institution, for filtering the river Thames beneath its bed.

Why does water, unlike other liquids, increase in volume, as it cools down to its point of congelation?

Because, by this peculiar law, it may answer certain important purposes in the economy of nature, which may be demonstrated as follows:—the water which covers so large a portion of the surface of the globe, is one of the most efficient means of equalizing its temperature, and rendering those parts habitable, which would otherwise be bound up in perpetual frost, or scorched with intolerable heat. The cold air which rushes from the polar regions progressively abstracts the heat from the great natural basins of water, or lakes, till the whole mass is reduced to 40° (the freezing point being 32°); but at the former point, by a wise providence, the refrigerating influence of the atmosphere becomes nearly null; for the superficial stratum, by further cooling, becomes specifically lighter; and, instead of sinking to the bottom, as before, and displacing the warmer water, it now remains at the surface, becomes converted into a cake of ice, and preserves the subjacent water from the further influence of the cold. If, like mercury, it continued to increase in density to its freezing point, the cold air would continue to rob the mass of water of its heat, till the whole sunk to 32°, when it would immediately set into a solid stratum of ice, and every living animal in it would perish; and in these latitudes, a deep lake, so frozen, would never again be liquified. At the temperature of 40°, water is about 828 times heavier than atmospheric air.

Why is the expansion of water by cooling, and at the time of becoming ice, a great cause of destruction in northern climates?

Because, where ice forms in the crevices or cavities of stones, or when water, which has penetrated into cement, freezes, its expansion acts with the force of the lever or the screw, in destroying or separating the parts of bodies. Akin to this, are the mechanical powers of water, as rain, hail, or snow, in descending from the atmosphere; for in acting upon the projections of solids, drops of water, or particles of snow, and still more, of hail, have a power of abrasion: and a very soft substance, from its mass assisting gravitation, may break a much harder one.

The rupture of iron and lead pipes by freezing, has been cursorily noticed elsewhere.* The most interesting experiments upon the subject are, according to Brande, those of Major Williams. Bomb-shells, about 13 inches in diameter, and more than 2 inches thick, were filled with water; the fuse-holes were then plugged with iron bolts—and thus charged, were exposed to the open air, at a temperature between 40° and 19°. At the moment of congelation, the plugs were thrown out, and the ice protruded through the fuse-hole. When the plug was duly secured, the shell itself burst. The greatest difference observed in those experiments, between the bulk of water before and after congelation, was :174 :184. Exposed to the air, ice loses considerably in weight, by evaporation.

Why is water, as a chemical agent, frequently resolved into its elements?

Because they are respectively concerned in the production of new compounds. Thus, when chloride of phosphorus acts upon water, its chlorine combines with the hydrogen of the water to form muriatic acid, and the phosphorus and oxygen unite to form phosphorous acid. In other cases, bodies decompose water by the absorption of oxygen only, and the hydrogen is liberated in the gaseous form; but there is no instance in which the hydrogen is absorbed, so as to cause the evolution of gaseous oxygen.—*Brande.*

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* See DOMESTIC SCIENCE, p. 14.

Why is the decay of marble buildings materially hastened by the water of the atmosphere?

Because of its great *solvent* powers: the calcareous and alkaline elements of stones being particularly liable to this kind of operation. The carbonic acid, which this water holds in solution, also increases its power of dissolving carbonate of lime, or marble; and in the neighbourhood of great cities, where the atmosphere contains a large proportion of this principle, the solvent powers of the rain exposed to it must be greatest. Whoever examines the marble statues in the British Museum, which have been removed from the exterior of the Parthenon, will be convinced that they have suffered from this agency; and an effect distinct in the pure atmosphere and temperate climate of Athens, must be upon a higher scale in the vicinity of other European cities, where the consumption of fuel produces carbonic acid in great quantities.—*Sir H. Davy.*

Why do metals rust in the exterior of buildings?

Because of the oxydating powers of water; which, by supplying oxygen in a dissolved or condensed state, enables the metals to form new combinations. Thus, metallic substances, such as iron, copper, bronze, brass, tin, and lead, whether they exist in stones, or are used for support or connexion in buildings, are liable to be corroded by water, holding in solution the principles of the atmosphere.—*Sir H. Davy.*

Why does wood exposed to the air so soon decay?

Because, not only the rain, but even the vapour in the air, attracted by the wood, gradually reacts upon its fibres, and assists decomposition, or enables its elements to take new arrangements. Hence it is, that none of the roofs of ancient buildings, more than one thousand years old, remain, unless it be such as are constructed of stone; as those of the Pantheon at Rome, and the tomb of Theodric at Ravenna, the cupola of which is composed of a single block of marble. The pictures of the Greek masters, which were painted on the wood of the *abies*, or pine of the Mediterranean, likewise, as we are informed by Pliny, owed their destruction, not to a change in the colours, nor to the alteration of the calcareous ground on which they were painted, but to the decay of the tablets of wood on which the intonaco or stucco was laid. Amongst the substances employed in building, wood, iron, tin, and lead, are most liable to decay from the operation of water; then marble, when exposed to its influence in the fluid form. Brass, copper, granite, sienite, and porphyry, are more durable.—*Sir H. Davy.*

Why do some stones decay sooner than others?

Because much depends upon the peculiar nature of their constituent parts. Thus, when the feldspar of the granite rocks contains little alkali or calcareous earth, it is a very permanent stone; but when, in granite, porphyry, or sienite, either the feldspar contains much alkaline matter, or the mica, schorl, or hornblende, much protoxide of iron, the action of water, containing oxygen and carbonic acid, on the ferruginous elements, tends to produce the disintegration of stone. The kaolin, or clay, used in most countries for the manufacture of porcelain or china, is generally produced from the feldspar of decomposing granite, in which the cause of decay is the dissolution and separation of the alkaline ingredients.

This and the three previous illustrations are abridged from the Dialogue *Pola, or Time*, in the posthumous work of Sir H. Davy, already named. We have nowhere seen the philosophy of creation and decay more beautifully illustrated than in this treasurable little volume.

Why is marble used for sculpture and architecture in preference to harder substances?

Because their durability is not in proportion to their hardness; and marble, though much softer than granite, resists longer the attacks of air and moisture.

Why is the temperature of the sea more uniform than that of any inland water, exposed to the atmosphere, and not a hot spring?

Because it possesses in itself a peculiar source of caloric, owing to a variety of causes, the operation of which is unknown to us. The vast body of the water, and the perpetual agitation to which it is exposed, render it less liable to be affected by outward changes of temperature; and this is particularly the case at a considerable depth below the surface; at its upper part, however, it possesses an extensive range of temperature at different seasons of the year. On the shores of England, the surface of the sea is seldom, in the severest weather, lower in its temperature than 40°, or higher, in the hottest summer, than 65°; whereas the heat of rivers, especially when they are shallow and their currents slow, rises higher and sinks lower than either of these points.—*Booth.*

Why does seawater soon grow offensive by keeping?

Because of the decomposition of the animal and vegetable matters which it contains in suspension; these, like all organic bodies, being peculiarly liable to change, and the salt in the water not being sufficient to preserve them from decay.

Why is the sea usually of a green colour?

Because, probably, of vegetable matter, and perhaps, partially, of two elementary principles, iodine and brome, which it certainly contains, though these are possibly the results of decayed marine vegetables. These give a yellow tint when dissolved in minute portions in water, and this mixed with the blue of pure water would occasion seagreen.—*Sir H. Davy.*

Why is it erroneous to suppose that the salt in the sea has been gradually augmented by saline particles brought into it by rivers?

Because this conclusion is totally inadequate to explain the immense quantity of salt existing in the whole mass of the ocean. If the average depth of the sea be ten miles, and it contain 2½ per cent of salt, were the water entirely evaporated, the thickness of the saline residue would exceed one thousand feet.—*Bakewell's Geology.*

Connected with the depth of the sea, the following interesting question has been noticed in a German Journal. Whether in the sea there be depths where no creature is able to live, or whether a boundary be assigned to organic life within those depths, cannot be ascertained. It, however, clearly appears from the observations made by Biot, and other naturalists, that fishes, according to their different dispositions, live in different depths of the ocean.

Why is the Mediterranean of superior saltness to other seas?

Because the Mediterranean expends, by evaporation, three times more water than it receives; the fresh water being so carried off from the surface.

Why is the Dead Sea so called?

Because no living creature is to be found in it.

Why is it said, that "nothing sinks in the Dead Sea"?

Because of its extreme saltness. Mr. Madden, a recent traveller, bathed in this sea: he could lie, like a log of wood, on the surface, without stirring hand or foot, as long as he chose; but with much exertion he could just dive sufficiently deep to cover all his body, when he was again thrown on the surface, in spite of his endeavours to descend lower. On coming out of the water, Mr. Madden found his body coated with it, and likewise with an incrustation of salt, about the thickness of a sixpence.

STEAM.

Why has steam such extraordinary power?

Because, in its constitution, two volumes of hydrogen, and one of oxygen, are condensed into two volumes. A cubic inch of water at 40° is expanded by heat into 1694 inches, or nearly a cubic foot of steam, at the temperature of 212°; at which point it is equal to the mean elasticity of the atmosphere, or thirty inches of mercury; when we see the phenomena of boiling.

Water is susceptible of compression, as was originally shown by Canton, and more lately by Mr. Perkins, who finds a pressure of 2000 atmospheres occasioned by a diminution of 1-12th its bulk. (*Phil. Trans.* 1820.) If submitted to very sudden compression, water becomes luminous, as has been shown by M. Desaignes. —*Brande.*

Why is steam considered universal in nature?

Because it is not only formed from water at its boiling point, but rises slowly and quietly from it at all temperatures, even below the freezing point. It is always found mixed with the permanent gases of the atmosphere, even in the driest weather; as may be seen by the dew on a glass of water fresh drawn from a well in summer. Its elasticity at the freezing point is equal to 0.200-inch of mercury, and its force increases in a geometrical progression for equal increments of temperature.

We have elsewhere quoted and simplified the applications of steam,* and, accordingly, here only notice its constitution, which could not with propriety be omitted: for, as Sir Humphry Davy observes, "the steam-engine in its rudest form was the result of a chemical experiment; in its refined state, it required the combinations of all the most recondite principles of chemistry and mechanics; and that excellent philosopher who has given this wonderful instrument of power to civil society, was led to the great improvements he made by the discoveries, of a kindred genius, on the heat absorbed when water becomes steam, and of the heat evolved when steam becomes water."

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* See MECHANICS, pp. 62 to 66.

MURIATIC ACID.

Why is muriatic acid gas termed, in more modern nomenclature, hydrochloric acid gas?

Because it consists of equal volumes of hydrogen and chlorine, mixed and exposed to light. The best mode of showing its composition, is to introduce into a small but strong glass vessel a mixture of the two gases, and to inflame them by the electric spark; no change of volume ensues, and muriatic acid gas results.—*Brande.*

Oil of vitriol poured upon common salt is a common method of purifying the chambers of the sick; the chlorine, which is thus produced, being a powerful disinfectant. Common salt will remove fruit and wine stains from linen, from the salt being a compound of sodium and chlorine. Sir H. Davy observes upon the first of these processes, "When common salt is decomposed by oil of vitriol, it was usual to explain the phenomenon by saying, that the acid, by its superior affinity, aided by heat, expelled the gas, and united to the soda. But, as neither muriatic acid nor soda exists in common salt, we must now modify the explanation, by saying, that the water of the oil of vitriol is first decomposed; its oxygen unites to the sodium, to form soda, which is seized on by the sulphuric acid, while the chlorine combines with the hydrogen of the water, and exhales in the form of muriatic acid gas."

Why is muriatic acid, dissolved in water, called spirit of salt?

Because it is commonly procured by distilling a mixture of dilute sulphuric acid with common salt; as, 32 parts of salt, and 22 of sulphuric acid, diluted with one third its weight of water. The quantity of real acid in muriatic acid of different densities, is best ascertained by the quantity of pure carbonate of lime, (Carrara marble, for instance) which a given weight of the acid dissolves. Every 50 grains of the carbonate are equivalent to 37 of real acid.—*Brande.*

Muriatic acid is much employed in the arts. It is the best test for silver: if a single drop be poured into any solution containing this metal, a copious precipitate ensues, owing to the affinity of this acid for the silver, and the insolubility of the muriate of silver thus formed. Muriatic acid dissolves tin and lead.

Why is muriatic acid recommended for cleaning old books and prints?

Because, though it removes the stains of common ink, it does not affect printers' ink. For the latter use, add half an ounce of red lead to three ounces of common muriatic acid. Where writings have been effaced for fraudulent purposes with this acid, sulphuret of ammonia, and prussiate of potash, will revive the writing and discover the artifice. Very old writing may be revived in this way. If indigo and oxide of manganese be added to common ink, it will prevent its being effaced by chlorine.—*Parkes.*

With various bases, muriatic acid forms the salts called muriates; and muriates, when in a state of dryness, are actually chlorides.

NITROGEN.

Why is nitrogen also called azote?

Because an animal immersed in it is immediately suffocated (from α, *privative*, and ζωη, *life*): but, if that term be taken in its strict sense, all gaseous bodies (excepting atmospheric air) might be included under it; for even oxygen itself will not indefinitely support life: moreover, nitrogen, as it exists in the atmosphere, mixed with oxygen, appears to be absolutely essential to animal life; for no other gas can be substituted for it. If we consider the term nitrogen as merely implying that it is a component of nitric acid, it is explicit and unobjectionable. We, therefore, adopt it in preference to that of azote.—*Brande.*

Whether nitrogen is or is not a simple body has been much discussed among eminent chemists, without any conclusive result. In Silliman's *American Journal* for 1829, we read of a discovery of nitrogen gas issuing in almost a pure state from the earth, through three springs, in Hoosick, New York. According to Trousset, the gas emitted by the skin is pure nitrogen; and Mr. Faraday has proved that if sea-sand, after ignition, be handled, it will yield an azotic impregnation from the skin, which the sand itself would not do.

Professor Emmett recommends the preparation of nitrogen by dipping zinc into fused nitrate of ammonia: it is instantly oxidized and dissolved, and nitrogen and ammoniacal gases are evolved. Every grain of the metal furnishes nearly a cubic inch of the gas; while the ammonia, which also escapes, becomes wholly condensed, as soon as it enters into the water of the pneumatic cistern.

Why is there so much nitrogen in atmospheric air, seeing that it is injurious to animal life?

Because it dilutes and modifies the oxygen of the atmosphere, so as to prevent too rapid combustion, and stimulating respiration. Dr. Lambe observes, that "if the proportions of oxygen and nitrogen were reversed in atmospheric air, the air taken in by respiration would be more stimulant, the circulation would become accelerated, and all the secretions would be increased; the tone of the vessels, thus stimulated to increased action, would be destroyed by over excitement, and, if the supply from the stomach were not equal to the consumption, the body must inevitably waste and decay.

Why is nitrous oxide popularly called "laughing-gas"?

Because it produces a certain degree of pleasurable excitement, often accompanied by laughter, in those who inhale it. It was discovered by Dr. Priestley, in 1772, but was first accurately investigated by Sir Humphry Davy, in 1779. The best mode of procuring it is to expose nitrate of ammonia to the flame of an argand lamp, in a glass retort. When the temperature reaches 400° Fahrenheit, a whitish cloud will begin to project itself into the neck of the retort, accompanied by the copious evolution of gas, which must be collected over mercury for accurate researches, but for common experiments may be received over water.

In Sir Humphry Davy's volume of *Researches*, concerning nitrous oxide, are many interesting details of its effects when respired. Sir Humphry describes those upon himself thus:—"Having previously closed my nostrils and exhausted my lungs, I breathed four quarts of nitrous oxide from and into a silk bag. The first feelings were similar to giddiness; but in less than half a minute, the respiration being continued, they diminished gradually, and were succeeded by a sensation analogous to gentle pressure on all the muscles, attended by an highly pleasurable thrilling, particularly in the chest and the extremities. The objects around me became dazzling, and my hearing more acute. Towards the last inspiration the thrilling increased, and at last an irresistible propensity to action was indulged in. I recollect but indistinctly what followed: I know that my motions were various and violent. These effects very soon ceased after respiration. In ten minutes I had recovered my natural state of mind. The thrilling in the extremities continued longer than the other sensations. Almost every one who has breathed this gas, has observed the same things. On some few, indeed, it has no effect whatever, and on others the effects are always painful." The experiment cannot be made with impunity, especially by those who are liable to a determination of blood to the head.

Why is nitric acid so called?

Because it is usually obtained by distilling purified nitre with sulphuric acid; this, however, is only sufficiently pure for ordinary purposes.

Nitric acid stains the greater number of animal substances of a yellow colour, and is hence used in producing yellow patterns upon coloured or woollen goods; it is used in fumigations, to destroy contagious and infectious matter, more especially in inhabited apartments, where chlorine would prove injurious. For this purpose, nitrate of potassa (nitre) and sulphuric acid are mixed in a saucer, and the evolution of the acid vapour aided by a gentle heat. In pharmacy, and a variety of other processes, it is susceptible of interesting applications: it is used for etching on copper, and as a solvent for tin,* in the preparation of valuable mordants, used by dyers and calico printers. It is an important agent in metallurgy, and especially in the art of assaying.—*Brande.*

For the purposes of the arts, it is commonly used in a diluted state, and contaminated with the sulphuric and muriatic acids, by the name of *aqua fortis.* A compound, made by mixing two parts of the nitric acid with one of muriatic, known formerly by the name of *aqua regia*, and now by that of *nitro-muriatic acid*, has the property of dissolving gold and platina.

Why is oxalic acid also called acid of sugar?

Because it is most commonly procured by the action of nitric acid on sugar.

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* In a recent German Journal, M. Mitscherlich mentions that iron, tin, and several other metals, may be put into, and even boiled in nitric acid, of 1.522 specific gravity, without the least effect; whilst zinc is immediately oxidized and dissolved.

AMMONIA.

Why is ammonia also called volatile alkali?

Because it converts most vegetable blues to green, and the yellows to red—properties which belong to the alkalies. The change of colour thus effected by ammonia is, however, distinguished from that produced by the *fixed* alkalies, by the return of the original tint, when the ammonia flies off by exposure. It saturates the acids, and produces an important class of ammoniacal salts, which are recognised by the evolution of ammonia, when they are triturated with potassa, soda, or lime.—*Brande.*

Why is sal ammoniac so called?

Because it was first made in the neighbourhood of the temple of Jupiter Ammon. According to Pliny, there were large inns in the vicinity of this famous temple, where the pilgrims, who came to worship, lodged; and who usually travelled on camels. The proprietors of these stables had some contrivance for preparing and concentrating the urine of these beasts, and the salts which it produced were afterwards sublimed in glass vessels for sale. Another account is, that ammoniacal salt was abundantly obtained from the blood of the victims who were slaughtered in honour of the god.

Why should liquid ammonia be kept in well-stopped bottles?

Because it loses ammonia, and absorbs carbonic acid, when exposed to the air.

Why is ammonia generally used in a liquid state?

Because, being next to hydrogen and carburetted hydrogen, the lightest of all the gaseous bodies, it has a great affinity for water. Now, though water is incapable of dissolving either hydrogen or nitrogen, yet when these are united in ammonia, their nature is so changed, that they become very soluble in water; that fluid having the power of taking up and condensing nearly 670 times its own bulk of ammoniacal gas; and when thus saturated, the solution is lighter than an equal volume of water, in the proportion of 875 to 1000.

Why is ammonia important in dyeing?

Because of its extensive use in making archil. A Florentine merchant, about the year 1300, having accidentally observed that stale urine, which always contains ammonia, imparted a very fine colour to a certain species of moss, &c., made experiments, and thus learned to prepare archil.—*Berthollet.*

A recent French Journal states, that *aqua ammonia* will give to new brandy all the qualities of that of the oldest date. Five or six drops of the ammonia are to be poured into each bottle of brandy, and shaken well, that it may combine with the acid, on which the taste and other qualities of the new liquor depend.

Why is ammonia so abundantly found in nature?

Because all putrifying animal and vegetable substances furnish it, in proportion to the quantity of nitrogen which they contain. It is, however, now generally procured by dry distillation of bones, horns, &c. Besides various uses in the arts, in chemical researches, and in medicine, ammonia combines with carbonic acid, and forms the article known as *volatile salts*, which are likewise obtained from coal soot, and from the waste liquor collected in the manufactories of coal gas. It has also an useful domestic application in aiding the lightness of bread; which is explained by its great volatility, and the heat of baking. Another and more extensively useful combination of ammonia, is with muriatic acid, forming muriate of ammonia, or *sal ammoniac*, originally fabricated in Egypt, from the soot of the dung of camels, burnt as fuel. It is now made in Europe, and is used by dyers to prevent tin from precipitating; in tinning metals, to cleanse the surface, and prevent them oxidizing by heat; and in the assay of metals, to discover the presence of iron; dissolved in nitric acid, it also forms the *aqua regia* of commerce.

Native ammonia is found in the vicinity of volcanoes, in some of the mountains of Tartary and Thibet, and in some of the Tuscan lakes. It has also been detected by Dr. Marcet in seawater. On pit coal it may also be sometimes seen in a yellowish white powder.

Why is old decomposed dung comparatively useless as manure?

Because, as soon as dung begins to decompose, it throws off its volatile parts, which are the most valuable and most efficient.

Why is soot a powerful manure?

Because it possesses ammoniacal salt, empyreumatic oil, and charcoal, which is capable of being rendered soluble by the action of oxygen, or pure vital air.

Why are the stem and leaves of the beet-root valuable?

Because, when dried and burned, they yield ashes so rich in alkali, that it melts easily by heat, and surpasses many of the common varieties of potassa.

SULPHUR.

Why are common pyrites roasted to obtain sulphur?

Because, the fumes being received into a long chamber of brickwork, the sulphur is gradually deposited; it is then purified by fusion, and cast into sticks.

Why will a roll of sulphur, when suddenly seized in a warm hand, crackle, and sometimes fall in pieces?

Because the action of heat is unequal, the sulphur conducting it but slowly, and having little power of cohesion.

Sulphur is one of the few elements which occur in nature in their simple form. It is a well known mineral substance, found in large quantities in the neighbourhood of volcanoes, and as an article of commerce is chiefly brought from the Mediterranean. The effects of heat upon sulphur are very curious. It is readily melted and volatilized, and begins to evaporate at 170°, and to fuse at 105°. At 220° it becomes completely fluid; between 226° and 228° it begins to crystallize; between 230° and 284° it is as liquid as clear varnish, and of an amber colour; at about 320° it begins to *thicken*, and acquire a red colour, and on increasing the heat, it becomes so thick that it will not pour. Between 428° and 572°, the colour is a red brown; from 572° to the boiling point it becomes thinner, but never so fluid as at 248°; the deep red brown colour continues till it boils. It sublimes (this term is used to denote the evaporation of a solid) at 600°, and condenses into the form of a powder, or, as it is termed, of *flowers*. When poured into water, in complete fusion, it becomes of the consistency of wax, and of a red colour; it may then be used for taking impressions from engraved stones, and hardens upon cooling. In a French Journal we read, "though it is well known that sulphur which has been recently fused does not immediately recover its former properties, no one suspected that it required whole months, and even a longer period, fully to restore it."

Why is sublimed sulphur, for delicate purposes, washed with hot water?

Because it is always slightly sour. The purity of sulphur may be estimated by gradually heating it upon a piece of platinum leaf; if free from earthy impurities, it should totally evaporate. It should also be perfectly soluble in boiling oil of turpentine.

Why is sulphuretted hydrogen of easy production?

Because sulphur, in its ordinary state, always contains hydrogen, which it gives off during the action of various bodies for which it has a powerful attraction. Berzelius, by heating sulphur with oxide of lead, remarked the formation of water, but in such small and indefinite quantities, as induced him to adopt the generally received opinion, that the presence of hydrogen is accidental, and that it is not an element of sulphur. This illustration is quoted by Mr. Brande in his valuable *Manual.* It is indeed simple and beautiful, since the reader need not be reminded of the ready production of oxygen from heating oxide of lead, and the formation of water by the combination of oxygen and hydrogen.

Of all the gases, sulphuretted hydrogen is perhaps the most deleterious to animal life. A green-finch, plunged into air which contains only 1-1500th of its volume, perishes instantly. A dog of middle size is destroyed in air that contains 1-800th; and a horse would fall a victim to an atmosphere containing 1-250th. Dr. Chaussier proves, that to kill an animal, it is sufficient to make the sulphuretted hydrogen gas act on the surface of its body, when it is absorbed by the inhalants.

Why is sulphur used in bleaching?

Because, when burned, its fumes combine with the oxygen of the atmosphere, and thus produce sulphurous acid gas. This first reddens blue colours and then destroys them: it is much used in whitening silk and straw-work. According to Pliny, it was used in his time for bleaching wool. Upon some colouring matters, however, as that of cochineal, sulphurous acid has scarcely any action; and when it does destroy colour, the original tint may often be recovered by a stronger acid. A red rose, for instance, is bleached by dipping into a solution of sulphurous acid; but the colour is restored by immersion in diluted sulphuric acid.

Why has a gun a peculiar smell after firing?

Because of the sulphuret of potash formed by the exploded sulphur and nitre of the gunpowder.

SULPHURIC ACID.

Why is water necessary, with sulphurous acid oxygen, to produce sulphuric acid?

Because the acid gradually unites with a further proportion of oxygen, and the compound is taken up by the water. When sulphur is burned in *dry* oxygen gas, there is no change of volume. Again, on the mixture or dilution of sulphuric acid, great heat is given out by the further admixture of oxygen. Four parts of acid and one of water, produce, when suddenly mixed, a temperature=300°. According to Dr. Ure, the greatest heat is evolved by mixing 73 of acid with 27 of water.

Sulphuric acid is also obtained without nitre, by a patented process invented by Mr. Hill. "Coarsely powdered iron pyrites are submitted to a red heat, in cylinders communicating with a leaden chamber containing water; part of the sulphur, as it burns out of the pyrites, appears at once to pass into the state of sulphuric acid."—*Brande.*

Native sulphuric acid is not uncommon. In 1829, M. Egidi, druggist of Ascoli, witnessed in a spacious cavern a violent disengagement of sulphuric hydrogen, which, in contact with atmospheric air, became gradually decomposed, and produced water and sulphur; the latter deposited on the sides of the cavern, and principally formed sulphates of lime crystallized; and lastly, sulphuric acid, running down the sides of the cavern. Professor Eaton describes the natural occurrence of sulphuric acid in large quantities, both in a diluted and a concentrated state, in the town of Byron, ten miles south of the Erie canal. The place has been known in the vicinity, for seventeen years, by the name of the sour springs, and consists of a hillock 230 feet long and 100 broad, of an ash-coloured alluvion, containing an immense quantity of exceedingly minute grains of iron pyrites: it is mostly covered with a coat of charred vegetable matter four or five inches thick, and black as charcoal; the same kind of matter extends on all sides, from the base of the hillock over the plain. Its charred state is caused wholly by the sulphuric acid. In wet spring seasons, plants flowered on this hillock sooner than on the adjoining grounds; but as soon as the spring rains began to decline, then the vegetables withered away, and appeared as if scorched. About two miles east of this place is another sulphuric acid spring, still more remarkable in one respect. The quantity of water from this spring is in sufficient quantity to turn a light grist-mill; and yet there is so much sulphuric acid present in it, that the stream will constantly redden violets, and its water coagulate milk. It is supposed that the sulphuric acid is produced in some way by the decomposition of the pyrites in the soil.—*Silliman.*

Cases of poisoning by sulphuric acid are not unfrequent; the best antidotes are copious draughts of chalk and water, and of carbonate of magnesia and water.—*Orfila.*

Why is sulphuric acid also called oil of vitriol?

Because it was formerly obtained by the distillation of green vitriol. It is now procured by burning a mixture of about 8 parts of sulphur, and of nitre, in close leaden chambers containing water, by which the fumes produced are absorbed, and by evaporation the acid is procured in a more concentrated state.—*Parkes.*

Why should sulphuric acid always be kept closely stopped?

Because it rapidly absorbs water from the atmosphere; so that, in moist weather, 3 parts by weight increase to 4 in 24 hours.

Why is sulphuric acid important in dyeing blue?

Because it instantly dissolves indigo, which, at first deep purple, becomes blue by exposure to air, or by dilution.

PHOSPHORUS.

Why is phosphorus obtainable from bone earth?

Because of the phosphate of lime in bones; which, with water and sulphuric acid, yields phosphoric acid; this, mixed with charcoal, and distilled, yields phosphoret of carbon, and this by re-distillation becomes phosphorus. Thénard is of opinion that phosphorus cannot be entirely freed from charcoal, a minute quantity of which does not impair its whiteness. Does not this illustrate its easy combustion?

Mr. Parkes notes that phosphorus was accidentally discovered at Hamburg, in 1669, by an alchemist named Brandt, in his search after gold; and two years afterwards, one Kraft brought a small piece of phosphorus to London, on purpose to show it to the king and queen of England. Mr. Boyle afterwards discovered the process, which he described in the *Philosophical Transactions* for 1680, and in a little book which he published in the same year, entitled the *Aerial Noctiluca*. Mr. Boyle instructed Mr. Godfrey Hankwitz, of London, how to procure it from urine, so that he was the first who made it for sale in England; and he continued to supply all Europe with it for many years.

Why does phosphorus shine in the air in the dark, with a pale blue light?

Because of its very slow combustion, which is attended by the production of acid: hence the necessity of preserving it in water; this has a luminous property when agitated. The combustion ceases in close vessels, as soon as the greater part of the oxygen has been absorbed. This light is caused by a white smoke; but in air perfectly dry, phosphorus does not smoke, because the acid which is formed, and closely encases the combustible, screens it from the atmospherical oxygen

In the vacuum of the air-pump, phosphorus, in small pieces loosely enveloped in cotton, will generally inflame, and burn for some time, with a pale blue light: and, in the same circumstances, it more readily kindles if sprinkled with powdered resin or sulphur; alone, it does not inflame.—*Brande.*

M. Osam has described, in the *Bulletin Universel*, several new solar phosphori, which are far more powerful than those previously known. The curious reader will find them in the *Arcana of Science* for 1829. See also page 53 of the present volume.

Phosphorescent phenomena are not uncommon in nature. Phosphorescent fluor spar has lately been found in Siberia and Cornwall. The luminousness of the sea, especially in stormy weather, is supposed to be a phenomenon of this class; but its cause is involved in too much controversy for place here: it was formerly believed to be caused by the electrical friction of the waves, which explanation is no longer admitted. Humboldt attributes it to certain shining molluscæ, which emit light at pleasure, and to the decomposed parts of dead medusæ, &c.* We have elsewhere cursorily noticed the properties of certain phosphorescent bodies. (*See p.* 52.)

Phosphoretted hydrogen may be employed in some simple experiments. Thus, when bubbles of it are sent up into a jar of oxygen, they burn with much splendour: in chlorine, also, they burn with a beautiful pale blue light.

Why are brimstone matches used in phosphoric fireboxes?

Because the sulphur of the match readily combines with the phosphorus in the bottle, by friction against cork or wood, and inflames: indeed, phosphorus and sulphur combined are more inflammable than phosphorus.

Why is it difficult to light paper by the flame of phosphorus?

Because the paper becomes covered and protected by the acid formed by the combustion of the phosphorus. When perfectly dry, phosphorus inflames at a temperature of 60°.

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* The best recent paper on the subject (for the controversy is still rife among naturalists) will be found in the *Magazine of Natural History*, for July, 1830.

Why is the phenomenon called "Will-o'-the-Wisp" produced?

Because of the phosphuretted hydrogen gas in stagnant waters and marshy grounds; its origin being probably in the decomposition of animal substances. The peculiar odour of fishes, when putrifying, arises from the emission of this gas.

COAL GAS.

Why does coal, subjected in close vessels to a red heat, produce gas?

Because the carbon and bitumen, of which the coal consists, thus become volatilized; and hydrogen, holding carbon in solution, is the result: this gas, combining with the oxygen of the atmosphere, produces combustion and flame. These gaseous products contain also more or less sulphuretted hydrogen, and carbonic oxide and acid. Dr. Henry conceives *that* gas to have the greatest illuminating power, which, in a given volume, consumes the largest quantity of oxygen.

Dr. Clayton seems to have been the first who performed this experiment, with the view of artificial illumination; though its application to economical purposes was unaccountably neglected for about sixty years. At length, Mr. Murdoch, of the Soho Foundry, instituted a series of judicious experiments on the extrication of gas from the ignited coal; and succeeded in establishing one of the most capital improvements which the arts of life have ever derived from philosophical research and sagacity.—*Ure.*

The coal is placed in oblong cast-iron cylinders or retorts, which are ranged in furnaces, to keep them at a red heat, and all the volatile products are conveyed by a common tube into a condensing vessel, kept cold by immersion in water; and in which, the water, tar, pitch, ammoniacal and other condensable vapours, are retained.—*Brande.*

The production of hydrogen gas in a tobacco-pipe, by filling the bowl with powdered coal, then luting it over, and placing it in a fire,—is well known; but even more familiar are the alternate bursting out and extinction of those burning jets of pitchy vapour, which, as Dr. Arnott aptly observes, "contribute to render a common fire an object so lively, and of such agreeable contemplation in the winter evenings."

Why was gas adopted in cotton-mills soon after its invention?

Because of the peculiar softness, clearness, and unvarying intensity of its light. Its being free from the inconvenience and danger resulting from the sparks and frequent snuffing of candles, is a circumstance of material importance, tending to diminish the hazard of fire, and lessening the high insurance premium on cotton-mills.

Mr. Brande illustrates the economy of gas illumination, by examining the value of the products of distillation of a chaldron of coals, the average cost of which may be considered as £2. It should afford

1¼ Chaldron of Coke, at 20s.	£1	5	0
24 Gallons of Tar and Ammoniacal Liquor at 1d.	0	2	0
1200 cubic feet of Gas, at 13s. per 100 C. F. .	7	16	0
	£9	3	0

The history and economy of gas-lighting have been copiously illustrated in several volumes exclusively devoted to the subject; as well as by the experimenting skill of some eminent chemists, as Messrs. Henry, Brande, Ure, Accum, and others. From one of these works, aided by the Reports of the late Sir William Congreve, we learn that in the year 1814 there was only one gasometer in Peter-street, Westminster, of 14,000 cubic feet, belonging to the Chartered Gas Light Company, then the only company established in

London. In 1827 there were four great companies, having, altogether, gasometers at work capable of containing in the whole 917,940 cubic feet of gas, supplied by 1,315 retorts, and these consuming 33,000 chaldrons of coal in the year, producing 41,000 chaldrons of coke; the whole quantity of gas generated annually being upwards of 397,000,000 cubic feet; by which 61,203 private, and 7,268 public or street, lamps are lighted, in the metropolis. In addition to these great companies, there were several private establishments, whose operations are not included in the foregoing statements; for, it appears that where more than fifty lights are required, a coal-gas apparatus will be found profitable. Thus, the gas for the office of the *Morning Chronicle* newspaper is made on the premises.

According to Mr. Murdoch's statement, presented to the Royal Society, 2,500 feet of gas were generated from 7 cwt.= 784 lb. of cannel coal. This is nearly 3½ cubic feet for every pound of coal, and indicates judicious management. The price of the best Wigan cannel is 13½*d.* per cwt. delivered at Manchester; or about 8*s.* for the 7 cwt. About one-third of the above quantity of good common coal, at 10*s.* per ton, is required for fuel to heat the retorts. Nearly two-thirds of the weight of the coal remain in the retort, in the form of coke, which is sold on the spot at 1*s.* 4*d.* per cwt. The quantity of tar produced from each ton of cannel coal, is from 11 to 12 ale gallons. This tar is now extensively used as paint for out-buildings, &c.; and the ammoniacal liquor, also a result of the process, is turned to still more advantageous account, in the manufacture of carbonate of ammonia; (*see p.* 119) so that nothing is lost.

Why is it necessary that the cylinders or retorts should be redhot?

Because the gas may be produced instantly the coals are introduced. If, on the other hand, coal be put into a coal retort, and slowly exposed to heat, its bitumen is merely volatilized, in the state of condensable tar. Little gas, and that of inferior illuminating power, is then produced.

Why does coke burn without smoke?

Because it is the distilled coal remaining in the retorts after the above process, and is consequently freed from all gases and vapours. Dr. Arnott observes, that "a pound of coke produces nearly as much heat as a pound of coal; but we must remember that a pound of coal gives only three-quarters of a pound of coke, although the latter is more bulky than the former."

Why are the gaseous products passed through quick-lime and water?

Because the sulphuretted hydrogen, and carbonic oxide and acid, may thus be absorbed; while the carburetted hydrogen gases are transmitted sufficiently pure for use into gasometers, whence the pipes issue for the supply of streets, houses, &c.

Why is a gasometer so called?

Because it enables the manufacturers of gas to *mete*, or measure, with accuracy, the quantity of gas expended, in proportion to the number of jets or burners made use of. The essential conditions of any apparatus for this purpose, are, that the pressure on the gas, while passing through the measurer, shall at all times be uniform: and that it shall register truly when that pressure is very small, and when the current of gas is very feeble.

The gas is conveyed or laid on to the premises of the consumers, by pipes called *mains*, which, in London, in the year 1824, extended 900 miles. Other methods, have, however, been adopted for its conveyance; and, in 1827, there was at Manchester an itinerant gasometer, capable of holding more than 1000 cubic feet of gas; this being mounted upon wheels, and filled with gas from the gasometer at the works, was transported about the streets of Manchester, and delivered into the gas-holders of the Company's customers.

Why is it important that the holes in the gas-burner be not too large?

Because, if this point be not attended to, the gas will be incompletely burnt. Increased length of flame makes imperfect combustion, and diminished intensity of light.

Mr. Accum gives the following interesting statement of gas-burners. "An argand burner, which measures in the upper rim half an inch in diameter between the holes from which the gas issues, when furnished with five apertures, 1-25th part of an inch in diameter, consumes two cubic feet of gas in an hour, when the gas flame is 1½ inch high. The illuminating power of this burner is equal to three tallow candles, eight in the pound. An argand burner, three-fourths of an inch in diameter, as above, and perforated with holes 1-30th of an inch in diameter (probably fifteen in number) consumes three cubic feet of gas in an hour, when the flame is 2½ inches high; giving the light of four candles, eight to the pound. And an argand burner, seven-eighths of an inch diameter, as above, perforated with eighteen holes, 1-32nd of an inch diameter, consumes, when the flame is three inches high, four cubic feet of gas per hour, producing the light of six tallow candles, eight to the pound. The height of the glass chimney should never be less than five inches.

Why is cannel coal best adapted for distillation?

Because it contains most bitumen, and least sulphur. A pound of good cannel coal, properly treated in a small apparatus, will yield five cubic feet of gas; equivalent in illuminating power to a mould candle, six in the pound. On a great scale, however, 3½ cubic feet of good gas are all that should be expected from one pound of coal. A gas jet, which consumes half a cubic foot per hour, affords a steady light equal to that of the above candle.

Why does carburetted hydrogen give out, during its combustion, much more light than the subcarburetted?

Because of the larger quantity of carbon disengaged by the former; but if the mixture with oxygen be in such proportions as at once to burn the whole of the charcoal in its gaseous combinations, without previous deposition, the light becomes blue, and is greatly reduced in intensity.

Why is the flame of a candle of various colours?

Because of the different stages of combustion in it. Thus, at the bottom part, where the inflammable gases are given off in the smallest quantity, and where they are most intimately mixed with the air, the combustion is at once complete, and the light is blue and faint; the centre part, where the particles of charcoal, owing to a less admixture of oxygen, are thrown off in a solid state, and become incandescent before they are finally burnt, is white and highly brilliant; and the upper, where the charcoal is in still greater quantity, and much of it finally escapes combustion, is red and dull, as is seen when a candle requires snuffing.

Dr. Ure, a few years since, made a set of experiments on the relative intensities of light, and duration of different candles, the result of which is contained in the following table:—

Number in a pound.	Duration of a Candle.	Weight in grains.	Grs. consumed per hour.	Proportion of light.	Economy of light.	Candles equal 1 Argand.
10 Mould	5 h. 9 m.	682	132	12¼	68	5.7
10 Dipped	4 36	672	150	13	65½	5.25
8 Mould	6 31	856	132	10½	59½	6.6
6 ditto	7 2½	1160	163	14¾	66	5.0
4 ditto	9 36	1787	186	20¼	80	3.5
Argand oil Flame.			512	69.4	100	

Why do those flames, whose products are only gaseous matter, give very little light?

Because the quantity of light which flame emits is dependent upon the incandescence of minute particles of solid matter, which are thrown off during combustion. The light of a stream of ignited hydrogen is scarcely visible in the day-light; but if a small coil of platinum wire be suspended in it, or some solid body, in very fine powder, such as the oxide of zinc, be projected through it, it becomes very luminous.

OIL GAS.

Why is oil gas cheaper than coal gas?

Because purified coal gas seldom contains more than 40 per cent. in volume of olefiant gas, while oil gas generally affords about 75 per cent.: hence its superiority for burning, and the relatively small quantity consumed. Thus oil, by being allowed to trickle into a redhot retort, half filled with coke or pieces of brick, to increase the heated surface, is decomposed, and yields a large quantity of gas, which is much richer in carburetted hydrogen than coal gas, and therefore much better fitted for the purposes of illumination. It contains no mixture of sulphuretted hydrogen, and requires no other purification than passing through a refrigerator; and as less of it is required for any given quantity of light, the atmosphere of a room is less heated and contaminated by its combustion. It is, however, considerably more expensive than the gas from coal; although the first outlay of capital for a manufactory upon a large scale is less, on account of the smaller size of the necessary pipes and apparatus. The commonest whale oil, or even pilchard-dregs, quite unfit for burning in the usual way, afford abundance of excellent gas. A gallon of whale oil affords about 90 cubical feet of gas, of an average specific gravity of 0.900; and an argand burner, equal to seven candles, consumes a cubical foot and a half per hour. Its economy may be judged from the following table:—

Argand burner, oil gas, per hour	¾d.
Argand lamps, spermaceti oil	3d.
Mould candles	3½
Wax candles	1s. 2d.

Mr. Brande adds, that a pint of the best sperm oil, weighing about 13 ounces, burns, in a well trimmed argand, about ten hours. And by a series of experiments, conducted with every requisite caution, he found, that to produce the light of ten wax candles for one hour, there were required—

2600 cubical inches of pure carburetted hydrogen, or olefiant gas.
4875 . . . . oil gas.
13120 . . . . coal gas.

Why is oil used by the Portable Gas Company?

Because they are enabled to compress the gaseous matter obtained from oil to about one-thirtieth of its volume, or into a certain new liquid compound, colourless or opalescent, yellow by transmitted, green by reflected light; and combustible, burning with a dense flame. Hence its *portability.* When the bottle containing it is opened, evaporation takes place from the surface of the liquid; but this vapour soon ceases, and the remainder is comparatively fixed.

Why is gas from wood but ill adapted for illumination?

Because it is so deficient in the compounds of carbon and hydrogen. In manufactories, however, of charcoal in iron retorts, for the making of gunpowder, the gas which is given off is led by a pipe under the cylinders, and is economically employed in maintaining their heat.

ROSIN GAS.

Why is rosin gas even more advantageous than oil gas?

Because rosin is of lower price, and less liable to fluctuations of value, than oil: indeed, the cost of the gas is stated at one-fourth that of oil; and the illuminating power of rosin gas, when compared with that from coal, is as two and a half to one, while it is of greater purity than that from coal or oil.

For the origin of this improvement we are indebted to Mr. J. F. Daniell, the distinguished meteorologist: his mode of treating the rosin is, to dissolve by gentle heat about 8 lbs. in a gallon of the essential oil, which is plentifully formed during the composition of oil for making gas, or of rosin itself. This solution was allowed to trickle into the heated retort half filled with coke: thus, from 1000 to 1200 cubit feet of gas are obtained from 1 cwt. of rosin, and rather more than the original quantity of volatile oil is condensed, which is again employed for the solution. Mr. Daniell patented this means about three years since, and an apparatus on the plan has been erected by M. Martineau for the London Institution.

The burners consume about 1000 cubit feet of gas per day, obtained by 100 lbs. of common rosin, at about 6*s*., dropped with oil of turpentine on heated iron cylinders, in the proportion of 10 gallons of turpentine to 100 lbs. rosin; but the cost of the turpentine is not included in the 6*s*., as the same oil may be used over and over again, for any length of time.

Mr. Brande thus illustrates the advantages of rosin gas:—"The sources of supply are as inexhaustible, and more generally distributed, than those of the coal; and the forests of America, France, Spain, and Italy, yield the turpentine in quantities only limited by the demand. Many large towns in this country, in America, France, Holland, and the Netherlands, have already adopted the use of this gas. The elegance and simplicity of the manufacture, and the comparatively small capital required for the erection of the works, will also give it the preference in the creation of new establishments."

Returning to the comparative value of different hydro-carburetted gases, for the purpose of illumination, it seems evident, from Dr. Henry's experience, that, whatever be their source or composition, it may be most accurately determined by the quantity of oxygen required to saturate equal volumes. In other words, quotes Mr. Brande, the illuminating powers of the different gases will be proportioned to the number of volumes of the gaseous carbon condensed into one volume of the gas; and of these, the oxygen consumed, and the carbonic acid produced, afford an accurate measure.

HYDROCYANIC ACID.

Why is hydrocyanic acid so called?

Because it consists of hydrogen, and a gaseous compound, cyanogen, so styled by M. Gay Lussac, because it is the principle which generates blue, from two Greek words, signifying the blue-maker: or it may be obtained by means of Prussian blue; whence it is also called *prussic acid.* The acid thus obtained, has a strong pungent odour, very like that of bitter almond; its taste is acrid, and it is highly poisonous, so that the inhalation of its vapour should be avoided. It volatilizes so rapidly as to freeze itself.

From the experiments of M. Majendie, it appears, that the pure hydrocyanic acid is the most violent of all poisons. When a rod dipped into it is brought in contact with the tongue of an animal, death ensues before the rod can be withdrawn. If a bird be held a moment over the mouth of a phial containing this acid, it dies. In the *Annales de Chimie* for 1814, we find this notice: M. B., Professor of Chemistry, left by accident upon a table, a flask containing alcohol impregnated with prussic acid; the servant, enticed by the agreeable flavour of the liquid, swallowed a small glass of it. In two minutes, she dropped down dead, as if struck with apoplexy.

Hydrocyanic acid may generally be detected by its very peculiar odour. Scheele supplies this test: to the suspected liquid add a solution of green vitriol or copperas, and afterwards drop in pure potassa in slight excess, and after a short exposure to the air, redissolve the precipitate in muriatic acid. If hydrocyanic acid be present, the tint of prussian blue will appear. By this means one ten-thousandth part of the acid may be detected in water. Another test, in which copper is used, will, however, detect one twenty-thousandth of the acid in water. We must render the liquid containing the hydrocyanic acid slightly alkaline with potash, add a few drops of sulphate of copper, and afterwards sufficient muriatic acid to redissolve the excess of oxide of copper. The liquid will appear more or less milky, according to the quantity of hydrocyanic acid present. M. Orfila recommends nitrate of silver as a test, by which the acid will be precipitated in the form of cyanure of silver.

PROPERTIES OF METALS.

Why did the ancients designate the seven metals known to them by the names of the planets?

Because they were supposed to have some hidden relation: each being denoted by a particular symbol, representing both the planet and the metal.

Gold . . . was the	Sun.
Silver	Moon.
Mercury	Mercury
Copper	Venus.
Iron	Mars.
Tin	Jupiter
Lead	Saturn.

Why are some metals called native?

Because they occur pure or alloyed, and have but a feeble attraction for oxygen; such as platinum, gold, silver, mercury, and copper. Metals are also found combined with simple supporters of combustion; the chief of these are metallic oxides. Metals combined with simple inflammables, include native metallic sulphurets. Metals in combination with acids, include metallic salts.—*Abridged from Brande.*

Why are some metals called native alloys?

Because they are found combined with other metals.

Why are metals refined by fire?

Because advantage is taken of some property in which the metal operated upon may differ from those with which it is alloyed, or from which it is desired to separate it. These differences may consist of the facility or difficulty of oxidation; in their tendency to volatilize; in the temperature required for fusion, and in their relative specific gravities.

Metals, when exposed to the action of oxygen, chlorine, or iodine, at an elevated temperature, generally take fire, and, combining with one or other of these three elementary dissolvents, in definite proportions, are converted into earthy or saline-looking bodies, devoid of metallic lustre and ductility, called oxides, chlorides, or iodides.

Why have the metals, as a class, a peculiar lustre?

Because of their great power of reflecting light, in consequence of their opacity. Mr. Brande observes: "their opacity is such, that, when extended into the thinnest possible leaves, they transmit no light; silver-leaf, only one hundred-thousandth of an inch in thickness, is perfectly opaque. Gold is perhaps the only exception, which, when beaten out into leaves one two-hundred-thousandth of an inch in thickness, transmits green rays of light."

Why are the polished metals peculiarly fit for burning mirrors?

Because they are very imperfect radiators and receivers of heat, but excellent reflectors both of light and heat.

POTASSIUM.

Why is potassium not found in an uncombined state?

Because of its great affinity for oxygen. All that has hitherto been obtained has been procured by chemical means from the potash of commerce.

Why did Sir H. Davy discover potassium by the agency of Voltaic electricity upon pure potash?

Because he was thus enabled to detach the oxygen, and then the alkaline base appeared in small bubbles having the lustre and outward characters of quicksilver.

Why is potassium important to the philosophical chemist?

Because it is capable of detecting and separating oxygen wherever it may exist, and however intimate and energetic may be the nature of its combinations. By its means water may be detached from the most highly rectified alcohol and ether; and, by its decomposition, hydrogen gas will be evolved. Potassium also combines with phosphorus, sulphur, and hydrogen; it forms metallic alloys with gold, silver, mercury, and some other metals; at a red heat it will decompose glass; and is even capable of reducing all the metallic oxides.—*Parkes.*

Potassium was discovered in 1807, by Sir Humphry Davy: he obtained it by submitting caustic potassa, or potash, to the action of Voltaic electricity; the metal was slowly evolved at the negative pole. Gay Lussac, and Thénard, first procured it by heating iron turnings to whiteness in a curved gun-barrel, and melting potash to come in contact with the turnings, when, air being excluded, potassium was formed, and collected in the cool part of the tube.

Why does potassium burn with a beautiful flame on water?

Because the potassium decomposes the water and absorbs the oxygen, while the hydrogen of the water escapes and takes fire by the heat which the rapidity of the action produces.

Why does sulphuric acid, when dropped on chlorate of potassa, cause it to ignite?

Because of the evolution of oxide of chlorine. A mixture of sulphuret of antimony, and the salt suddenly deflagrates with a bright puff of flame and smoke. Matches tipped with this inflammable mixture are now in common use, and are inflamed by contact with asbestos saturated with sulphuric acid. Berzelius gives the following as the best composition for the matches: 30 parts powdered chlorate of potassa, 10 of powdered sulphur, 8 of sugar, 5 of gum arabic, and a little cinnabar. The sugar, gum, and salt, are first rubbed together into a paste with water; the sulphur is then added, and the whole being thoroughly beaten together, small brimstone matches are dipped in, so as to retain a thin coat of the mixture upon their sulphuretted points. A similar compound is employed in percussion gun-locks: gunpowder, made into a paste with water and chlorate of potash, is dropped in small copper caps adapted to the tubular touch-hole of the gun, when a blow inflames the powder, and communicates to that in the barrel. Fulminating mercury is, however, now substituted for this composition, which is found to rust the touch-hole.

Note to "STEAM," *page* 113.

In the whole range of English literature, perhaps there is nothing more curious than the following prophecy respecting Steam, in Dr. Darwin's *Botanic Garden*, published in 1789, but written, it is well known, at least twenty years before the date of its publication:

> Soon shall thy arm, unconquer'd steam, afar
> Drag the slow barge, or drive the rapid car;
> Or on wide waving wings expanded bear
> The flying chariot through the fields of air.
> Fair crews triumphant leaning from above
> Shall wave their fluttering 'kerchiefs as they move;
> Or warrior bands alarm the gaping crowd,
> And armies shrink beneath the shadowy cloud:
> So mighty Hercules o'er many a clime
> Waved his huge mace in virtue's cause sublime;
> Unmeasured strength with early art combined,
> Awed, served, protected, and amazed mankind.

END OF PART XII.

KNOWLEDGE FOR THE PEOPLE:

OR THE

PLAIN WHY AND BECAUSE.

PART VII.—MECHANICS.

MECHANICS.

INTRODUCTORY.

Why are certain truths termed physical?

Because they explain the greater part of the phenomena of nature, the term physical being derived from the Greek word signifying *nature;* an appellation distinguishing them from *chemical* truths, which regard particular substances, and from *vital* truths, which have relation only to living bodies.—*Arnott.*

Why is an atom so called?

Because of its origin from a Greek word signifying *that which cannot be farther divided;* or, an exceedingly minute resisting particle.

Why is the term attraction used?

Because the atoms of which the visible universe is built up, whether separate, or already joined into masses, tend towards all other masses, with force proportioned to their proximity: as, when any body presses or falls towards the great mass of the earth, or when the tides on the earth rise towards the moon.

Why is the term repulsion used?

Because, under certain known circumstances, as of heat diffused among the particles, their mutual *attraction* is countervailed or resisted, and they tend to separate with force proportioned to their proximity: as, when heated water bursts into steam, or when gunpowder explodes.

Why is the term inertia used?

Because it denotes that the atoms, in regard to motion, have about them what may be figuratively called a *stubbornness*, tending always to keep them in their existing state, whatever it may be; in other words, that bodies neither acquire motion, nor lose motion, nor bend their course in motion, but in exact accordance to some force applied.

This, and the three preceding definitions, are derived from the Synopsis of Dr. Arnott's valuable *Elements of Physics*, Part I. third edit. 1828; the author pertinently observing, that "a person comprehending fully the import of these four words, *atom*, *attraction*, *repulsion*, *inertia*, may predict or anticipate correctly, very many of the facts and phenomena which the extended experience of a life can display to him."

Why are not men sensible of the rapid motion of the earth?

Because all things move at the same rate. Whatever *common* motions objects may have, it does not interfere with the effect of a force producing any new relative motion among them. All the motions seen on earth are really only slight differences among the common motions: as, in a fleet of sailing ships, the apparent changes of place among them are, in truth, only slight alterations of speed or direction in their individual courses.

Why does a spire, or obelisk stand more securely on the earth, than a pillar stands on the bottom of a moving wagon?

Because the motion of the earth is uniform, and not that the earth is more at rest than the wagon. Were the present rotation of our globe to be arrested but for a moment, imperial London, with its thousand spires and turrets, would be swept from its valley towards the eastern ocean, just as loose snow is swept away by a gust of wind.—*Arnott.*

Why does a ball, let drop from the hand, fall with greater velocity the nearer it approaches the earth?

Because, owing to the inertia of matter, any force continuing to act on a mass which is free to obey it, produces in the mass a quickening or accelerated motion; for, as the motion given in the first instant, continues afterwards without any farther force, merely on account of the inertia, it follows that as much more motion is added during the second instant, and as much again during the third, and so on. A falling body, therefore, under the influence of attraction, is, as it were, a reservoir, receiving every instant fresh velocity and momentum (or quantity of motion). The height of a precipice, or the depth of a well, may be judged of with considerable accuracy, by marking the time required for a body to fall through the space. A body falls four times as far in two seconds as in one, although the velocity, at the end of two seconds, is only doubled.—*Arnott.*

A body falls by gravity precisely 16 1-16 feet in a second, and the velocity increases according to the squares of the time: *viz.*

In ¼″ (quarter of a second)	a body falls	1 foot.
½″ (half a second)	ditto	4
1 second	ditto	16
2 ditto	ditto	64
3 ditto	ditto	144

The power of gravity at two miles distance from the earth, is four times less than at one mile; at three miles, nine times less; and so on. It goes on lessening, but is never destroyed.

Meteoric stones, falling from great heights, bury themselves deep in the earth, by the force of their gradually acquired velocity.

Why are we said to know of nothing which is absolutely at rest?

Because the earth is whirling round its axis, and round the sun; the sun is moving round his axis, and round the centre of gravity of the solar system; and, doubtless, round some more remote centre in the great universe, carrying all his planets and comets about his path.

One of the grand laws of nature is, that all bodies persevere in their present state, whether of motion or rest, unless disturbed by some foreign power. Motion, therefore, once begun, would be continued for ever, were it to meet with no interruption from external causes, such as the power of gravity, the resistance of the medium, &c.

Dr. Arnott adduces several familiar illustrations of motions and forces. Thus, all falling and pressing bodies exhibit *attraction* in its simplest form. *Repulsion* is instanced in explosion, steam, the action of springs, &c. Explosion of gunpowder is repulsion among the particles when assuming the form of air. Steam, by the repulsion among its particles, moves the piston of the steam-engine. All elasticity, as seen in springs, collision, &c. belongs chiefly to repulsion. A spring is often, as it were, a reservoir of force, kept ready charged for a purpose; as when a gun-lock is cocked, a watch wound up, &c.

Why does a billiard ball stop when it strikes directly another ball of equal size, and the second ball proceed with the whole velocity which the first had?

Because the action which imparts the new motion is equal to the reaction which destroys the old. Although the transference of motion, in such a case, seems to be instantaneous, the change is really progressive, and is as follows: The approaching ball, at a certain point of time, has just given half of its motion to the other equal ball; and if both were of soft clay, they would then proceed together with half the original velocity; but, as they are elastic, the touching parts at the moment supposed, are compressed like a spring between the balls; and by their expanding, and exerting force equally both ways, they double the velocity of the foremost ball, and destroy altogether the motion in the other.

Why is the uniformity of motion essential to rational conjecture or anticipation as to future events?

Because, it is by assuming, for instance, that the earth will continue to turn uniformly on its axis, that we speak of *to-morrow* and of *next week*, &c. and that we make all arrangements for future emergencies: and were the coming day or season, or year, to arrive sooner or later than such anticipation, it would throw such confusion into all our affairs that the world would soon be desolate.

To calculate futurities, then, (observes Dr. Arnott) or, to speak of past events, is merely to take some great uniform motion as a standard with which to compare all others; and then to say of the remote event, that it coincided, or will coincide, with some described state of the standard motion. The most obvious and best standards are the whirling of the earth about its axis, and its great revolution round the sun. The first is rendered very sensible to man by his alternately seeing and not seeing the sun, and it is called *a day;* the second is marked by the succession of the seasons, and it is called *a year.* The earth turns upon its axis about 365 times while it is performing one circuit round the sun, and thus it divides the year into so many smaller parts; and the day is divided into smaller parts, by the progress of the earth's whirling being so distinctly marked, in the constantly-varying directions of the sun, as viewed from any given spot on the face of the earth. When advancing civilisation made it of importance to man to be able to ascertain with precision the very instant of the earth's revolution, connected with any event, various contrivances were introduced for the purpose. Such have been sun-dials, where the shadow travels progressively round the divided circle; the uniform flux of water through a prepared opening; the flux of sand in a common hour-glass, &c. But the very triumphs of modern ingenuity and art are those astronomical clocks and watches, in which the counted equal vibrations of a pendulum, or balance-wheel, have detected periodical inequalities even in the motion of the earth itself, and have directed attention to unsuspected disturbing causes, important to be known.

Why, when a body is carried below the surface of the earth, does its weight become less?

Because the matter then above it is drawing it up, instead of down, as before. A descent of a few hundred feet makes a sensible difference, and at the centre of the earth, if man could reach it, he would find things to have no weight at all; and there would be neither up nor down, because bodies would be equally attracted in all directions.—*Arnott.*

Why is a horseman standing on the saddle enabled to leap over a garter extended over the horse, (the horse passing under the garter,) and to light upon the saddle at the opposite side?

Because, the exertion of the performer, in this case, is not that which he would use were he to leap from the ground over a garter at the same height. In the latter case, he would make an exertion to rise, and at the same time, to project his body forward. In the case, however, of the horseman, he merely makes that exertion which is necessary to rise directly upwards to a sufficient height to clear the garter. The motion which he has in common with the horse, compounded with the elevation acquired by his muscular power, accomplishes the leap.

Why does a walking stick help a man on a journey?

Because he pushes against the ground with the stick, which may be considered as compressing a spring between the earth and the end of his stick, which spring is therefore pushing up as much as he pushes down; and if, at the time, he were balanced in the scales of a weighing beam, he would find that he weighed just as much less as he were pressing with his stick.

Why does a person wishing to leap over a ditch or chasm, make a run first?

Because the motion thereby acquired may help him over. A standing leap falls much short of a running one.

These facts also illustrate the same principle:—From a glass of water suddenly pushed forward on a table, the water is spilt or left behind, but if the glass be already in motion, as when carried by a person walking, and if it be then suddenly stopped by coming against an impediment, the water is thrown or spilt forward. Again, the actions of beating a coat or carpet with a cane to expel the dust; of shaking the snow from one's shoes by kicking against the door-post; of knocking a dusty book against a table, or shutting it violently.

Why is a man jumping from a carriage at speed, in great danger of falling, after his feet reach the ground?

Because his body has as much forward velocity, as if he had been running with the speed of the carriage; and unless he advance his feet as in running, he must as certainly be dashed to the ground, as a runner whose feet are suddenly arrested.—*Arnott.*

Why will the recoil of a fowling-piece hurt the shoulder, if the piece be not held close to it?

Because the piece recoils with as much motion or momentum in it as the ball has; but the momentum in the gun being diffused through a greater mass, the velocity is small, and easily checked.

Why does a sky-rocket ascend?

Because, after it is lighted, the lower part is always producing a large quantity of aëriform fluid, which, in expanding, presses not only on the air below, but also on the rocket above, and thus lifts it. The ascent is aided also by the recoil of the rocket from the part of its substance, which is constantly being shot downwards.—*Arnott.*

Why does a hare, though much less fleet than a greyhound, often escape it?

Because the greyhound is, with the hare, a comparatively heavy body, moving at the same or greater speed in pursuit. The hare *doubles*, that is, suddenly changes the direction of her course, and turns back at an oblique angle with the direction in which she had been running. The greyhound, unable to resist the tendency of its body to persevere in the rapid motion it had acquired, is urged forward many yards before it is able to check its speed and return to the pursuit. Meanwhile the hare is gaining ground in the other direction, so that the animals are at a very considerable distance asunder when the pursuit is recommenced.

Why are a large and small ship sometimes seen sailing with the same velocity?

Because the surface of canvass or sail which they spread to catch the force of the wind, is proportioned to the difference of resistance which the water offers to the two.

Why are ships so often destroyed by running foul of each other at sea?

Because when two bodies moving in opposite directions meet, each body sustains as great a shock as if, being at rest, it had been struck by the other body with the united forces of the two. Thus, if two ships of 500 tons burden encounter each other, sailing at ten knots an hour, each sustains the shock, which, being at rest, it would receive from a vessel of 1000 tons burden, sailing ten knots an hour.

Why are carriages often overturned in quickly rounding corners?

Because the inertia carries the body of the vehicle in the former direction, while the wheels are suddenly pulled round by the horses into a new one. A loaded stage-coach running south, and suddenly turned to the east or west, strews its passengers on the south side of the road. Where a sharp turning in a carriage road is unavoidable, the outside of the bend should always be made higher than the inside, to prevent such accidents.

Why were the battering rams of the ancients such formidable engines of war?

Because they allowed the concentrated efforts of many hands, and a considerable duration of action, so as to give at last one great and sudden shock.

The action of gunpowder on bullets, although appearing so sudden, is still not an instantaneous, but a gradual, and therefore accelerating motion; and accordingly we find the effect to depend much on the length of the piece along which the force pursues the ball.—*Arnott.*

Why will a cannon or musket ball, shot quite horizontally, touch the ground of a level plane just as soon as another ball dropped at the same instant directly from the cannon's mouth?

Because the forward or projectile motion does not at all interfere with the action of gravity. This fact, observes Dr. Arnott, which most persons, before consideration, would be disposed to doubt, makes strikingly sensible the extraordinary speed of a cannon ball; *viz.* which has already carried it 600 or 800 feet before touching, during the half second that a ball dropped from the hand of a standing person requires to reach the earth. This fact also explains why, for a long range, the gun must always be pointed more or less upwards.—*Elements of Physics.*

The velocity of a musket ball is, on an average, 1,600 feet per second, and its range half a mile.

Why is this range only half a mile, whereas, by theory, it ought to be ten miles?

Because it is retarded by the resistance of the air.

In velocities exceeding 1,600 feet per second, the resistance of the air is greatly increased; hence the absurdity of giving balls too great an initial velocity. To give a bullet the velocity of 2000 feet per second, requires half as much more powder as to give it the velocity of 1,600 feet; yet after both have moved 400 feet, the difference between the velocity of each is reduced to 8 feet per second. A 24-pound ball, moving at the rate of 2000 feet per second, meets a resistance of 800 pounds.

If a body could be projected upwards with the velocity of 36,700 feet in a second, it would never return; and as it receded from the earth, its weight or gravity would diminish. At present, the greatest velocity with which we can project a body, does not exceed 2000 feet per second. A bullet rising a mile above the surface of the earth, loses 1-2000th part of its weight.—*Notes in Science.*

Lieut. Helwig, of Prussia, has invented a process for measuring the time occupied by a ball or bullet in passing through a certain space; by making the ball liberate the works of a time-keeper at the moment when it quits the mouth of the piece, and in making it also stop the time-keeper at the moment when it strikes an obstacle. Thus, he finds that a light body, of the same calibre with the bullet, moves, at the commencement, with much greater velocity than the latter; equal charges being used.

Steam cannon has not yet been found to realize all the formidable expectations which it had raised; but Mr. Perkins has estimated the projectile force of steam to be ten times greater than that of gunpowder, in throwing a ball to a given distance.

While on the subject of fire-arms, we may mention that an ingenious Frenchman proposes to fix a small mirror, 0.47 of an inch in the side, near the mouthpiece, so that the person using it shall see the reflexion of his own eye. In this way it is supposed that very exact aim may be taken; and the experiments made by various officers and sportsmen, are said to encourage the idea that this application may be useful.

Why will a bullet, fired against a door hanging freely on its hinges, perforate the same without agitating it?

Because the impression of the stroke is confined to one single spot, and sufficient time is not allowed for diffusing its action over the extent of the door. A pellet of clay, a bit of tallow, or even a small bag of water, discharged from a pistol, will produce the same effect.

Why is sea-sickness produced on shipboard?

Because man, strictly to maintain his perpendicularity, that is, to keep the centre of gravity always over the support of his body, requires standards of comparison, which he obtains chiefly by the perpendicularity or known position of things about him, as on land; but on shipboard, where the lines of the masts, windows, furniture, &c. are constantly changing, his standards of comparison are soon lost or disturbed. Hence, also, the reason why persons unaccustomed to the motion of a ship, often find relief by keeping their eyes directed to the fixed shore, where it is visible, or by lying on their backs, and shutting their eyes; and, on the other hand, the ill effects of looking over the side of the vessel at the restless waves of the sea.

Sea-sickness, observes Dr. Arnott, also depends partly on the irregular pressure of the bowels among themselves, and against the containing parts, when their inertia, or downward pressure, varies with the rising and falling of the ship.

Reasoning upon the last-mentioned facts, Mr. Pratt, of New Bond-street, has constructed an elastic or swinging seat, couch, or bed, for preventing the uneasy motions of a ship or carriage; the frame of which is suspended on juribals or joints, turning at right angles to each other; and an elasticity is produced both in the seat or cushion, and in the swinging frames, by the use of spiral metal springs, in the form of an hour-glass. A still more simple preventive was illustrated by Sir Richard Phillips, on his crossing from Dover to Calais, a few years since. He caused an arm-chair to be placed on the deck of the vessel, and being seated in it, he began to raise himself up and down, as on horseback. The passengers laughed at his eccentricity, but before they reached Calais, many of them were sea-sick, whilst Sir Richard continued to enjoy his usual health and vigour. We mentioned this experiment whilst making the same passage in the Royal George steam-boat, about a fortnight since; but no person aboard made the trial of its efficacy, although more than half of the number were sea-sick.

An embrocation has lately been invented, and secured by patent, for preventing or alleviating sea-sickness; this preparation is to be rubbed over the lower end of the breast-bone, and under the left ribs; but we cannot add our own testimony of its efficacy.

Why cannot sure aim be taken with a stone in a sling?

Because the point from which it should depart, cannot be accurately determined.

Why is the pendulum a time-keeper?

Because the times of the vibrations are very nearly equal, whether it be moving much or little; that is to say, whether the arc described by it be large or small.

A common clock is merely a pendulum, with wheel-work attached to it, to record the number of the vibrations; and with a weight or spring, having force enough to counteract the retarding effects of friction and the resistance of the air. The wheels show how many swings or beats of the pendulum have taken place, because at every beat, a tooth of the last wheel is allowed to pass. Now, if this wheel has sixty teeth, as is common, it will just turn round once for sixty beats of the pendulum, or seconds; and a hand fixed on its axis, projecting through the dial-plate, will be the second hand of the clock. The other wheels are so connected with this first, and the numbers of the teeth on them so proportioned, that one turns sixty times slower than the first, to fit its axis to carry a minute hand; and another, by moving twelve times slower still, is fitted to carry an hour-hand.—*Arnott.*

Why do clocks denote the progress of time?

Because they count the oscillations of a pendulum; and by that peculiar property of the pendulum, that one vibration commences exactly where the last terminates, no part of time is lost or gained in the juxtaposition (or putting together) of the units so counted, so that the precise fractional part of a day, can be ascertained, which each such unit measures.

The origin of the pendulum is traced to Galileo's observation of a hanging lamp in a church at Pisa continuing to vibrate long and with singular uniformity, after any accidental cause of disturbance. Hence he was led to investigate the laws of the phenomenon, and out of what, in some shape or other, had been before men's eyes from the beginning of the world, his powerful genius extracted the most important results.

The invention of pendulum clocks took place about the middle of the seventeenth century; and the honour of the discovery is disputed between Galileo and Huygens. Becher contends for Galileo, and states that one Trifler made the first pendulum clock at Florence, under the direction of Galileo Galilei, and that a model of it was sent to Holland. The Accademia del Cimento also expressly declared, that the application of the pendulum to the movement of a clock, was first proposed by Galileo, and put in practice by his son, Vincenzo Galileo, in 1649. Huygens, however, contests the priority, and made a pendulum clock before 1658; and he insists, that if ever Galileo had entertained such an idea, he never brought it to perfection. Beckmann says the first pendulum clock made in England, was constructed in the year 1662, by one Tromantil, a Dutchman; but Grignon affirms that the first pendulum clock was made in England, by Robert Harris, in 1641, and erected in Inigo Jones's church of St. Paul, Covent-garden.

Why does the pendulum move faster in proportion as its journey is longer?

Because, in proportion as the arc described is more extended, the steeper are its beginning and ending; and the more rapidly, therefore, the pendulum falls down at first, sweeps along the intermediate space, and stops at last.—*Arnott.*

Why is it extremely difficult to ascertain the exact length of the pendulum?

Because of the various expansion of metals, respecting which no two pyrometers agree; the changeable nature of the atmosphere; the uncertainty as to the true level of the sea; the extreme difficulty of measuring accurately the distance between the point of suspension and the centre of oscillation, and even of finding that centre; also the variety of terrestrial attraction, from which cause the motions of the pendulum are also liable to variation, even in the same latitude. In pursuing his researches, Capt. Kater discovered that the motions of the pendulum are affected by the nature of the strata over which it vibrates.

Why does the force of gravity determine how long the pendulum shall be in falling to the bottom of its arc, and how long in rising?

Because the ball of the pendulum may be considered as a body descending by its weight on a slope; a change in the force of gravity, therefore, would at once alter the rates of all the clocks on earth.—*Arnott.*

Why is the regulator of a watch merely a pin which bears against the balance-spring?

Because it slides backwards and forwards, so as to shorten or lengthen the part of the spring left free to bend, thus changing the degree of its stiffness; and, as the motion of the pendulum has relation to the force of gravity, so has the motion of the balance-wheel to the stiffness of the balance-spring.

Why do persons walking arm-in-arm, shake each other unless their steps correspond?

Because the centre of gravity in each body comes alternately over the right and over the left foot.

Why are certain metals malleable, or reducible into thin plates or leaves by hammering?

Because their atoms cohere equally in whatever relative situation they happen to be, and therefore yield to force, and shift about among each other, almost like the atoms of a fluid, without fracture or change of property.

Gold is remarkably malleable, for it may be reduced to leaves of the thinness of 282,000 to the inch. For gold-beaters the metal is first formed into rods, these are afterwards rolled or flattened into ribands, the riband is cut into portions, which are extended by hammering to great breadth and thinness, and which being again divided into portions, are hammered and extended to the thinness described.

Why are the steel chisels and tools used for cutting metals so frequently broken?

Because, requiring to be exceedingly hard, they proportionally lose, in regard to the extent of their elasticity. Cast iron, which is much harder than malleable or wrought iron, is very brittle, while soft iron and steel are the toughest things in nature.—*Arnott.*

Why does a smith, by hammering a piece of bar-iron, render it red hot?

Because he thereby compresses the metal. When air is violently compressed, it becomes so hot as to ignite cotton and other substances. An ingenious instrument for producing light for domestic uses has been constructed, consisting of a small cylinder, in which a solid piston moves air-tight: a little tinder, or dry sponge, is attached to the bottom of the piston, which is then violently forced into the cylinder: the air between the bottom of the cylinder and the piston becomes intensely compressed, and evolves so much heat as to light the tinder.—*Lardner.*

Why is the iron rim of a coach wheel heated before putting on?

Because the expansion of the metal occasioned by the heat, facilitates the operation of putting on the iron, while the contraction which follows, brings the joints of the wooden part together; and thus, binding the whole, gives great strength to the wheel.

Why does a bottle of fresh water, corked and let down 30 or 40 feet into the sea, often come up again with the water saltish, although the cork be still in its place?

Because the cork, when far down, is so squeezed as to allow the water to pass in or out by its sides, but on rising it, resumes its former size.

Why do bubbles rise on a cup of tea when a lump of sugar is dropped into it?

Because the sugar is porous, and the air which filled its pores then escapes to the surface of the tea, and the liquid takes its place.

Why are stalactites formed in the interior of caverns?

Because water percolates through their porous sides and roofs, and being impregnated with calcareous and other earths, assumes pendant forms.

Why is there an opening in the centre of the upper stone of a corn mill?

Because through this opening the grain is admitted and kept turning round between the stones, and is always tending and travelling outwards, until it escapes as flour from the circumference.

Why does a horse in the circus lean to the centre?

Because, when the horse moves round with the performer standing on the saddle, both the horse and rider incline continually towards the centre of the ring, and the inclination increases with the velocity of the motion: by this inclination their weights counteract the effect of the centrifugal force.

Why does water remain in a vessel which is placed in a sling and made to describe a circle?

Because the water, by its inertia of straightness, or centrifugal (or centre-flying) force, tends more away from the centre of motion towards the bottom of the vessel, than towards the earth by gravity.

Why does a spinning top stand?

Because, while the top is perfectly upright, its point, being directly under its centre, supports it steadily, and although turning so rapidly, has no tendency to move from the place; but if the top incline at all, the side of the peg, instead of the very point, comes in contact with the floor, and the peg then becomes a little wheel or roller, advancing quickly, and, with its touching edge, describing a curve somewhat as a skaiter does, until it becomes directly under the body of the top as before. It thus appears that the very fact of the top inclining, causes the point to shift its place, and so that it cannot rest until it come again directly under the centre of the top.—*Arnott.*

Why is a rocking-stone so called?

Because it consists of an immense mass, loosened in some convulsion of nature, and with a slightly rounded base resting on a flat surface of rock below, which is so nearly balanced, that one individual can move or *rock* it. This arises from the rounded body being disturbed from its middle position, and its centre of gravity seeking to return.

Of these rocks, called Loggan or Laggan stones, there are several among the picturesque barriers of the British coast.

Dr. S. Hibbert has very recently described a natural rocking-stone of granite, near the village of Loubeyrat, in the province of Auvergne, France. This stone appears to have been an object of religious worship, for, on the top of it were two figures, a cross, and a pedestal. Under the figures the word *pardon* is traceable, and other letters which probably alluded to the number of days of pardon which the cross gave to the venerator. The natural phenomenon of the rocking-stone probably became an object of superstitious veneration to its neighbourhood, and the figures and cross were the adoring tributes of the natives. Dr. Hibbert, however, thinks that the particular use to which rocking-stones were applied will ever remain in obscurity: "as they are products of every country where loose detached rocks of a particular structure have been submitted to the operation of atmospheric agents, it is to be expected that the fables assigned to their origin would be regulated by the peculiar mythology of the people among whom they have become the object of notice and wonder."

Why have all shot manufactories lofty towers, as seen on the southern bank of the Thames?

Because, in the manufacturing of shot, the liquid metal is allowed to fall like rain from a great elevation, as through these towers, and the cohesive principle gives rotundity to grains of shot. In its descent, the drops become truly globular, and before they reach the end of their fall they are hardened by cooling, so that they retain their shape.

Why does a porter lean forward when carrying a load?

Because his position must be regulated by the centre of gravity of his body and the load taken together. If he bore the load on his back, the line of direction would pass beyond his heels, and he would fall backwards. To bring the centre of gravity over his feet he accordingly leans forward.—If a nurse carry a child in her arms, she leans back for a like reason.

Why does a young quadruped walk much sooner than a child?

Because a body is tottering in proportion to its great altitude and narrow base. Now, the child has this latter, and learns to walk but slowly, because of the difficulty, perhaps in ten or twelve months, while the young of quadrupeds, having a broad supporting base, are able to stand, and even to move about almost immediately: but it is the noble prerogative of man to be able to support his towering figure with great firmness, on a very narrow base, and under constant change of attitude.—*Arnott.*

Why are the "safety coaches" built with the wheels far apart, and the luggage-receptacles beneath the body?

Because they may have a broader base, and thus be less liable to overturn.

Why do builders use the plummet, or plumb line?

Because, when applied to a body, it is a visible indication of the line of its centre of gravity.

Why do certain structures remain secure, although they have lost their perpendicularity?

Because the line of their centre of gravity remains within the base. The famous tower of Pisa was built intentionally inclining, to frighten and surprise; it is 130 feet high, and overhangs its base 16 feet. At Bologna are two celebrated leaning towers, one of which, the Asinelli, is 350 feet high, and 3½ feet out of the perpendicular. The other, the Garisenda, is about 130 feet in height, and inclines 8 feet from the perpendicular. Montfaucon, the celebrated antiquary, attributes the leaning of these towers to the sinking of the earth. He says, it appears, upon examination, that when the Garisenda tower bowed, a great part of it went to ruin, because the ground that the inclined side stood on was not so firm as the other, which may be said of all other towers that lean so; for "besides these two here mentioned, the tower for the bells of St. Mary Zobenica, at Venice, leans considerably to one side. So also at Ravénna, I took notice of another stooping tower, occasioned by the ground on that side giving way a little. In the way from Ferrara to Venice, where the soil is marshy, we see a structure of great antiquity leaning to one side. When the whole structure of the Garisenda stooped, much of it fell, as appears by the top."

The Monument, near London Bridge, inclines so much that timid people sometimes doubt its stability, and some years since its fall was a point of discussion. Salisbury and other of our cathedral spires or towers have lost something of their perpendicularity; Chesterfield, in Derbyshire, is proverbial for its zig-zag or wry spire.

The Monument is of the Doric order, and rises from the pavement to the height of 202 feet, containing within its shaft a spiral stair of black marble of 345 steps; the plinth is 21 feet square. It was begun in 1671, but was not completed till 1677; stone being scarce, and the restoration of London and its cathedral swallowing up the produce of the quarries. Mr. Elmes, in his Life of Sir Christopher Wren, the architect, tells us that the Monument was "at first used by the members of the Royal Society for astronomical experiments, but was abandoned on account of its *vibrations* being too great for the nicety required in their observations. This occasioned a report that it was unsafe; but its scientific construction may bid defiance to the attacks of all but earthquakes for centuries." The more recent fear of its instability was therefore only a revival of this alarm; which probably obtained some credence among weak persons, from its being erroneously attributed to Fellows of the Royal Society.

Why is it physically advantageous to turn out the toes?

Because the supporting base of a man consists of the feet and the space between them; and turning out the toes, without taking much from the length of the base, adds a good deal to the breadth.—*Arnott.*

Why do very fat people usually throw back their head and shoulders?

Because, by so doing, they keep the centre of gravity of the body over the base.

SIMPLE MACHINES.

Why have the "simple machines," as the lever, wheel and axle, plane, wedge, screw, and pulley, been long called the "mechanic powers?"

Because they were first used to raise great weights, or overcome great resistances. Hence the common error in supposing that they *generate* force, or have a sort of innate power for saving labour; whereas, neither simple machines nor mechanic powers save labour, in a strict sense of the phrase.

Why, then, are these machines advantageous?

Because they allow a small force to take its time to produce any requisite magnitude of effect. Thus, one man's effort, or any small power, which is always at command, by working proportionally longer, will answer the purpose of the sudden effort of many men, even of hundreds or thousands, whom it might be most inconvenient and expensive, or even impossible to bring together.

Why are there so many vain schemes for perpetual motions, and new mechanical engines of power?

Because the projectors do not understand the great truth, that no form or combination of machinery ever did or ever can increase, in the slighest degree, the quantity of power applied. Hence the futility of supposing that a lever, or great pendulum, or spring, or heavy fly-wheel, &c. can ever exert more force than has passed into it from some source of motion.—*Arnott.*

THE LEVER.

Why is a beam or rod of any kind, resting at one part on a prop or axis, which becomes its centre of motion, a lever?

Because such a contrivance was first employed to lift (*levare*, Latin) weights.

The lever, in mechanics, compensates power by space, and what is lost in power is gained in time. If the lever be 17 feet long, and the pivot or fulcrum be a foot from one end, an ounce placed on the other end will balance a pound placed on the near end. If, instead of an ounce, we place upon the long end the short end of a second beam or lever, supported by a fulcrum one foot from it, and then place the long end of this second lever upon the short end of a third lever, whose fulcrum is one foot from it; and if we put upon the end of this third lever's long arm an ounce weight, that ounce will move upwards a pound on the second lever's long arm; and this moving upwards, will cause the short end to force downwards 16 pounds at the long end of the first lever, which will make the short end of the first lever move upwards, although 256 pounds be laid upon it. The same effect continuing, a pound on the long end of the third lever, will move up a ton and three-quarters at the short end of the first lever, so that the touch of a child's finger, will move as much as two horses can draw.—*Notes in Science.*

Why did Archimedes reasonably enough say, "Give me a lever long enough, and a prop strong enough, and with my own weight I will move the world?"

Because there is no limit to the difference of intensity in forces, which may be placed in opposition to each other by the lever, except the length and strength of the material of which the levers must be formed. But he would have required to move with the velocity of a cannon-ball for millions of ages, to alter the position of the earth by the small part of an inch. This feat of Archimedes is, in mathematical truth, performed by every man who leaps from the ground, for he kicks the world away when he rises, and attracts it again when he falls back.—*Arnott.*

Why is a finger caught near the hinge of a shutting door so much injured?

Because the centre of action of the door moves through a space comparatively great, and acts with a great lever-advantage on a resistance placed near the fulcrum of the lever where there is little motion. Children pinching their fingers in this way, or in the hinge of the fire-tongs, where there is a similar action, wonder why the bite is so keen.

Why have pincers or forceps such extraordinary power?

Because they are double levers, of which the hinge is the common prop or fulcrum. Dr. Arnott thus illustrates the advantages of this machine:—In drawing a nail with steel nippers, we have a good example of the advantages of using a tool; 1. The nail is seized by teeth of steel, instead of by the soft fingers; 2. Instead of the griping force of the extreme fingers only, there is the force of the whole hand conveyed through the handles of the nippers; 3. The force is rendered, perhaps, six times more effective by the lever length of the handles; and, 4. By making the nippers, in drawing the nail, rest on one shoulder as a fulcrum, it acquires all the advantages of the lever or claw-hammer for the same purpose.

Why do lofty sails often cause open boats to upset?

Because the mast and sails set upon it are as a long lever, having the sails as the power, turning upon the centre of buoyancy of the vessel as the fulcrum, and lifting the balance or centre of gravity as the resistance.

Why may a boy, who cannot exert a direct force of 50lbs., by means of a claw-hammer, extract a nail, to which half a ton might be suspended?

Because his hand, perhaps, moves through eight inches, to make the nail rise one quarter of an inch. The claw-hammer also proves, that it is of no consequence whether the lever be straight or crooked, provided it produces the required difference of velocity between power and resistance. The part of the hammer resting on the plank, is the fulcrum, or prop.

Why does a combination of levers produce such extraordinary power?

Because if a lever, which makes *one* balance *four*, be applied to work a second lever which does the same, *one* pound at the long arm of the first, will balance *sixteen* pounds at the short arm of the second lever, and would balance *sixty-four* at the short arm of a third such, &c.—*Arnott.*

WHEEL AND AXLE.

Why is motion transmitted through a train of wheel-work by the formation of teeth upon the circumference of the wheels?

Because the indentures of each wheel fall between the corresponding ones of that in which it works, and ensure the action so long as the strain is not so great as to fracture the tooth.

Why is a heavy wheel sometimes used as a concentrator of force, or a mechanic power?

Because, by means of a winch, or a weight, or otherwise, motion or momentum is gradually accumulated in the wheel, and is then made to expend itself in producing some sudden and proportionally great effect.

The coining-presses of the Royal Mint are thus impelled by a fly-wheel, and generally complete a coin by one blow; and they strike, upon an average, 60 blows in one minute; the blank piece, previously prepared and annealed, being placed between the dies by part of the same mechanism. The number of pieces which may be struck by a single die of good steel, properly hardened and tempered, not unfrequently amounts, at the Mint, to between 3 and 400,000. There are eight presses frequently at work for ten hours each day, and each press produces 3,600 pieces per hour; but, making allowances for occasional stoppages, we may reckon the daily produce of each press at 30,000 pieces; the eight presses, therefore, will furnish a diurnal average of 240,000 pieces.

Why is it an error to account the fly-wheel a positive power?

Because, in common cases, it merely equalizes the effect of an irregular force. Thus, in using a winch to turn a mill, a man does not act with equal force all round the circle; but a heavy wheel, fixed on the axis, resists acceleration and receives momentum, while his action is above par, and returns it again while his action is below par, thus equalizing the movement. Again, in circular motion produced by a crank, when by the pressure of the foot on a treadle, we turn a lathe, or grindstone, or spinning-wheel, the force is only applied during a small part of the revolution, or in the form of interrupted pushes, yet the motion goes on steadily, because the turning grindstone, or wheel, or lathe, merely becomes a fly and reservoir, equalizing the effect of the force.

Why is the common winch in principle a wheel?

Because the hand of the worker describes a circle, and there is no difference in the result, whether an entire wheel be turning with the hand, or only a single spoke of the wheel.

Why is a man on a treadmill compelled to keep perpetually moving?

Because, being placed at the circumference of the wheel, his weight turns it, and he must move forward as fast as the wheel descends, so as to maintain his position continually at the extremity of the horizontal diameter of the wheel.

The invention of the treadmill is, by some persons, said to have been derived from a squirrel in a cylindrical wire cage.

WHEEL CARRIAGES.

Why have wheel carriages been advantageously substituted for sledges?

Because the rubbing or friction, instead of being between an iron shoe and the stones and irregularities of the road, is between the axle and its bush, which have surfaces smoothed and fitted to each other, and well lubricated.

Why does the wheel aid the progress of a carriage?

Because, while the carriage moves forwards, perhaps 15 feet, by one revolution of its wheel, the rubbing part, viz. the axle, only passes over a few inches of the internal surface of its smooth greased bush. Again, the wheel surmounts any abrupt obstacle on the road, by the axle describing a gently rising slope or curve; and by rising as on an inclined plane, and giving to the drawing animal the relief which such a plane would bring.—*Arnott.*

Why are wheels usually made of a dished form, that is, inclining outwards?

Because they thus acquire astonishing strength, indeed that of the arch, as contrasted with the flat or upright wheel; the dished form is farther useful in this, that when the carriage is on an inclined road, and more of the weight consequently falls upon the wheel of the lower side, the inferior spokes of that wheel become nearly perpendicular, and therefore support the increased weight more safely. The disadvantage of these wheels, however, is, that an inclining wheel naturally describing a curved path, the horses, in drawing straight forward, have to overcome this deviating tendency in all the wheels.—*Arnott.*

Why are axles made of steel, and the parts on which they bear of brass?

Because friction is universally diminished by letting the substances which are to rub each other be of different kinds. The swiftness of a skaiter, it may be observed, depends much on the dissimilarity between ice and steel.

Why are the fore-wheels of carriages smaller than the hind-wheels?

Because they facilitate the turning of the carriage. The advantage of the wheel is proportioned to the magnitude; the smaller wheel having to rise a steeper curve. It is not true, however, according to the popular prejudice, that the large hind-wheels of coaches and waggons help to push on the little wheels before them.—*Arnott.*

From these causes, continues the same ingenious writer, "the difference in performing the same journey of a mile by a sledge and a wheel carriage, is, that while the former rubs over every roughness in the road, and is jolted by every irregularity, the rubbing part of the latter, the axle, glides very slowly over about thirty yards of a smoothed oiled surface, in a gently waving line. It is ascertained that the resistance is thus reduced to 1-100th of what it is for a sledge."

Why do springs not only render carriages easy vehicles on rough roads, but much lessen the pull to the horses?

Because, where there is no spring, the whole load must rise with every rising of the road, and must sink with every depression, and the depression costs as much as the rising, because the wheel must be drawn up again from the bottom of it; but in a spring carriage, moving rapidly along, only the parts below the springs are moved, in correspondence with the irregularities, while all above, by the inertia of the matter, have a soft and steady advance.—*Arnott.*

Again, springs of carriages convert all percussion into mere increase of pressure: that is to say, the collision of two hard bodies is changed by the interposition of one that is elastic, into a mere accession of weight. It is probable, that under certain modifications, springs may be applied with great advantage to the heaviest waggons.

In surmounting obstacles, a carriage with its load being lifted over, the springs allow the wheels to rise, while the weights suspended on them are scarcely moved from their horizontal level.

Why are "under-springs" so advantageous in very modern carriages?

Because they insulate from the effects of shocks, all the parts, excepting the wheels and axletrees themselves. When only the body of the carriage is on springs, the horses have still to rattle the heavy frame-work below it, over all irregularities.

Why, in descending a hilly road, is it common to lock or fix one of the wheels of a carriage?

Because, the friction is then increased, and there is less chance of a rapid descent; the horses having then to pull nearly as much as on a level road, with the wheel free.

We have noticed a very effectual mode of "locking" the hind wheels of carriages, on the continent, by screwing a bar transversely, against the outer rim of the wheels; by this means, the wheels may be either partially or wholly locked, according to a powerful screw, in the centre of the bar. This mode is adopted by the Paris diligences; we first noticed it in a Swiss *calêche*, of great strength. The bar is rather unsightly, but our excellence in the construction of wheel-carriages should not lead us always to look for elegance, where convenience is a main point, as in a vehicle for travelling.

Why should a road up a very steep hill, be made to wind or zig-zag all the way?

Because, to reach a given height, the ease of the pull is greater, exactly as the road is made longer.

Why is it important to make roads as level as possible?

Because, a horse drawing on a road where there is a rise of one foot in twenty, is really lifting one twentieth of the load, as well as overcoming the friction, and other resistance of the carriage.—*Arnott.*

THE WEDGE.

Why are cutting instruments, knives, razors, the axe, &c. examples of the wedge?

Because at the same time that we pull them lengthwise, we press them directly forward, against the object. A saw, too, is a series of wedges.

Why does a razor, (if drawn lightly over the hand) dart into the flesh, whereas, if pressed against the hand with considerable force, it will not enter?

Because of the vibration of particles produced by the drawing action, which enables the razor to insinuate itself more easily. We witnessed an example, only a few days since, when a *bon vivant*, in a fit of mischievous ecstasy, seized a pointless table knife, and passed it very lightly down the back of his friend's coat. The injury was not immediately seen, but the cloth proved cut, from the collar to the waist; whereas, had the knife been heavily pressed against the cloth, the coat would have escaped injury, and the gay fellow the expense of his folly.

Why is the wedge so important an agent in the arts and manufactures?

Because it exerts enormous force through a very small space. Thus, it is resorted to for splitting masses of timber, or stones. Ships are raised in docks, by wedges driven under their keels. The wedge is the principal agent in the oil-mill. The seeds, from which the oil is to be extracted, are introduced into hairbags, and placed between planes of hard-wood. Wedges inserted between the bags, are driven, by allowing heavy beams to fall on them. The pressure thus excited is so intense, that the seeds in the bags are formed into a mass nearly as solid as wood.—*Lardner.*

The details of an extensive oil mill near Garrat are as follow:—A magnificent water-wheel, of 30 feet, turns a main shaft, which gives motion to a pair of vertical stones, raises the driving-beams, and turns a band, which carries the seed in small buckets from the floor to the hopper. The shock on the entire nervous system, produced by the noise of the driving-beams as they fall on the wedges, is not to be described. The sense of hearing for the time is wholly destroyed, and the powers of voice and articulation are vainly exerted. The noise is oppressive, though a rebound, comparatively tuneful, takes place, till the wedge is driven home; but afterwards the blows fall dead, and produce a painful jar on the nerves, affecting the auditor for some hours with a sense of general lassitude.

THE SCREW.

Why does a screw enable a small force to produce such prodigious effects?

Because every turn of the screw carries it forward in a fixed nut, or draws a movable nut along upon it, by exactly the distance between two turns of its thread: this distance, therefore, is the space described by the resistance, while the force moves in the circumference of the circle described by the handle of the screw; and the disparity between these lengths or spaces is often as a hundred or more to one.—*Arnott.*

Why may the screw be called a winding wedge?

Because it has the same relation to a straight wedge, that a road winding up a hill or tower has to a straight road of the same length and acclivity.

Why is the screw, in some respects, a disadvantageous contrivance?

Because it produces so much friction, as to consume a considerable part of the force used in working it.

Why do mathematical instrument makers mark divisions on their work with the screw?

Because it can easily be made with a hundred turns of its thread in the space of an inch, and at perfectly equal distances from each other. If we suppose such a screw to be pulling forward a plate of metal, or the edge of a circle, over which a sharp-pointed steel marker is placed, which moves up and down perpendicularly, the marker, if let down once for every turn of the screw, will make just as many lines on the plate; but, if made to mark at every hundredth or thousandth of a turn of the screw, which it will do with equal accuracy, it may draw a hundred thousand distinct lines in one inch.

Why may a printing press be said to do the work of fifty men?

Because a solitary workman, with his screw or other engine, can press a sheet of paper against types, so as to take off a clear impression; to do which without the press, the direct push of fifty men would be insufficient; and these fifty men would be idle and superfluous, except just at the instant of pressing, which recurs only now and then. This, and the two preceding illustrations, are almost literally from Dr. Arnott's works, in which the importance of having correct notions on the subject of the simple machines, or mechanical powers, is illustrated by many other familiar examples.

THE PULLEY.

Why is the pulley an advantageous machine?

Because, in such a construction, it is evident that the weight (let it be supposed ten pounds) is equally supported by each end of the rope, and that a man holding up one end, only bears half of it, or five pounds; but to raise the weight one foot, he must draw up the two feet of rope; therefore, with the pulley, he lifts five pounds two feet, where he would have to lift ten pounds one foot without the pulley.

Why have fixed pullies no mechanical advantage?

Because the weight just moves as fast as the power; yet such pullies are of great use in changing the direction of forces. A sailor, without moving from the deck of his ship, by means of such a pulley, may hoist the sail or the signal flag to the top of the loftiest mast.

Why is the pulley on ship-board called a block?

Because of the block or wooden mass which surrounds the wheel or wheels of the pulley. Hence the machinery for making these pullies is called *block-machinery*. Of that at Portsmouth, invented by Brunel, there is a set of magnificent models in the possession of the Navy Board. They consist of eight separate machines, which work in succession, so as to begin and finish off a two-sheaved block four inches in length.

Mr. Faraday, in a lecture at the Royal Institution in 1829, stated generally, that the block-machinery of Portsmouth, by adjustments, could manufacture blocks of one hundred different sizes; could, with thirty men, make one hundred per hour; and, from the time of its completion in 1804-5, to that day, had required no repairs from Maudslay, the original manufacturer. The total cost was £46,000, and the saving per annum, in time of war, was £25,000, after allowing interest for capital, and paying the expense of all repairs.

Why is a chair or bucket, attached to one end of a rope which is carried over a fixed pulley, used as a fire-escape?

Because a person, by laying hold of the rope on the other side, may, at will, descend to a depth equal to half of the entire length of the rope, by continually yielding rope on the one side, and depressing the bucket or chain by his weight on the other. In this case the pulley must be attached to some part of the building, or it is recommended that each chamber-floor of a dwelling-house should have a staple fixed near the exterior of a window, to which staple the pulley may be attached by a hook. This is, perhaps, the simplest fire-escape yet proposed, and we need scarcely add, the simpler the means the more likely is it to succeed in extreme danger.

FRICTION.

Why is the friction greater between pieces of the same substance, than between pieces of different substances, with dissimilar grains?

Because, it is supposed, of the roughnesses, or little projections in the former, mutually fitting each other, as the teeth of similar saws would.

"But for friction," observes Dr. Arnott, "men walking on the ground or pavement would always be as if walking on ice; and our rivers, that now flow so calmly, would all be frightful torrents."

Why does the friction of various woods against each other vary?

Because of their different degrees of hardness; the soft woods in general giving more resistance than the hard woods; thus, yellow deal affords the greatest, and red teak the least friction. Soft metals also produce greater friction, under similar circumstances, than those which are hard.—*G. Rennie.*

Why is the friction of surfaces, when first brought into contact, often greater than after their attrition has been continued a certain time?

Because the smoother the surfaces are the less will be the friction, and that process has a tendency to remove those minute asperities and projections on which the friction depends. But this has a limit, and after a certain degree of attrition the friction ceases to decrease.

Why does smearing the surfaces with unctuous matter diminish the friction?

Because it fills up the cavities between the minute projections which produce the friction.

Why has plumbago, or black lead, been substituted for oil in clocks and chronometers?

Because, when mixed with spirit, it readily adheres to the surface of a steel pivot, as well as to the inside of the hole in which it runs, so that the rubbing surfaces are no longer one metal upon another, but plumbago upon plumbago. These surfaces, by their mutual action, speedily acquire a polish inferior only to that of the diamond, and then the retardation of the machine from friction is reduced almost to nothing, and wear and tear from this cause is totally prevented.

Why are jewelled holes injurious to the pivots of watches and chronometers?

Because, sooner or later, however perfect the polishing may be, the hard substance of the jewel grinds and cuts the steel pivot, and the metallic particles clog the oil.

Why is a peculiar metal requisite for pivot-holes?

Because it must preserve the oil in a fluid state, have little friction with the steel pivot, and be in a degree softer than the pivot, for it is of less consequence that the hole be worn than the pivot. Brass is objectionable, on account of its liability to rust, and gold is too soft for the purpose. Now, an alloy possessing the above requisites has lately been discovered by Mr. Bennett, watchmaker, of Holborn. It consists of pure gold, silver, copper, and palladium, and its small expense, compared with that of jewels, is not its least recommendation.

STRENGTH OF MATERIALS.

Why is a hollow tube of metal stronger than the same quantity of metal as a solid rod?

Because its substance, standing further from the centre, resists with a larger lever. Hence, pillars of cast-iron are generally made hollow, that they may have strength, with as little metal as possible. Masts and yards for ships have been made hollow, in accordance with the same principle.

Why does a plank bend and break more readily than a beam, and a beam resting on its edges, bear a greater weight than if resting on its side?

Because the resisting lever is smaller in proportion as the beam is thinner. Where a single beam cannot be found deep enough to have the strength required in any particular case, as for supporting the roof of a house, several beams are joined together, and in a great variety of ways, as is seen in house-rafters, &c. which, although consisting of three or more pieces, may be considered as one very broad beam, with those parts cut out which do not contribute much to the strength.—*Arnott.*

Why is a beam, when bent by its weight in the middle, very liable to break?

Because the destroying force acts by the long lever, reaching from the end of the beam to the centre, and the resisting force or strength acts only by the short lever, from the side to the centre; while only a little of the substance of the beam on the under side is allowed to resist at all. This last circumstance is so remarkable, that the scratch of a pin on the under side of a plank, resting as here supposed, will sometimes suffice to begin the fracture.—*Arnott.*

Why is a suspension bridge more economical than an ordinary, or insistent bridge?

Because a suspension-bridge varies its curve so as to adapt it to any variation or partial excess in its load, in consequence of which, the strength of the chains may, with great precision, be adjusted to any required strain, and no more: while, in insistent bridges, the liability of the arch to a fatal derangement of its form by partial or excessive pressure, requires an enormous increase of weight and strength, beyond what is requisite for the mere support of its load, supposing it to be uniformly distributed.—*Ainger.*

Why is iron admirably adapted for the construction of suspension bridges?

Because the greater part of the weight of these bridges arises from the chains themselves, wherefore, the best material for the purpose, is that which has great tenacity with small weight; and iron is at the same time the most tenacious, and, excepting tin, the lightest of the common metals. A square inch of good iron requires about 25 tons to separate it,—and it will not be stretched or otherwise affected, with less than half that weight. Rope bridges, have, however, been introduced, with the advantages of economy and portability, into British India, where a rope-bridge, 160 feet in length, is so light and portable, that it has been several times set up and removed in a few hours.—*Ainger.*

We may here mention, that Mr. Bevan has found the strength or cohesion of cast-iron, to be upwards of 30,000 pounds to the square-inch, though much depends upon the mode of applying the force.

Why is iron best cemented by cast-iron?

Because pure iron, when surrounded by and in contact with cast-iron turnings, and heated, is carbonized very rapidly, so as to exhibit all the properties of steel.

Why is heated air now used in smelting iron?

Because it requires but three-fourths of the quantity of coal requisite, when cold air, that is, air not artificially heated, is employed for that purpose; while the produce of the furnace in iron, is at the same time greatly increased. It is supposed, that this improvement will accomplish a saving in the cost of the iron, in Great Britain, to the amount of at least 200,000*l.* a-year.—*Jameson.*

Why are piles for bridge-building, driven by great weights being suddenly let fall on them?

Because the body of the workman being too weak, to give a forcible downward push directly, he employs a certain time in carrying a weight up to such an elevation above his work, that when let fall, its momentum may do what is required. Here the continued efforts of the man in lifting the weight, to a height of perhaps thirty feet, may be just sufficient to sink into the earth one inch; and the continuance has, therefore, balanced forces, which are to each other in intensity, as thirty feet to an inch.—*Arnott.*

Why does an ill-built bridge generally flatten in the arch?

Because the builder has not sufficiently attended to the effect of the horizontal thrust of the arch on its piers. Each arch is an engine of oblique force, pushing the pier away from it. In some instances, one arch of a bridge falling, has allowed the adjoining piers to be pushed down towards it, by the thrust, no longer balanced, of the arches beyond; and the whole structure has given way at once, like a child's bridge, built of cards.—*Arnott.*

The principle of bridge-building is beautifully illustrated by the small toy-models; the stones being represented by separate pieces of wood, which the juvenile architect is required to form into an arch, or arches. It could be wished that the above and such scientific toys were better appreciated in England. They seem only to suit the caprice of the moment. Thus, the Chinese, Indian, and other puzzles, were but the favourites of a year, and Dr. Brewster's splendid kaleidoscope was less understood, and more abused, than any modern discovery.

Why do the great domes of churches resemble simple arches?

Because they have strength on the same principle, being in general, strongly bound at the bottom, with chains and iron bars, to counteract the horizontal thrust of the superstructure; this binding, in truth, resembling a pier all round. St. Peter's at Rome, and St. Paul's in London, are fine examples; as is also the large fir roof of the Basilica of St. Paul's. At Rome, the trusses are double, and placed fifteen inches asunder, which gives it, probably, more stability than if they were strapped and bound into single masses.

Why is the Gothic or pointed arch so universally admired for its strength and beauty?

Because it bears the chief weight on its summit or key-stone. Bishop Warburton, in his *Divine Legation*, supposes the Gothic arch to have been taken from an avenue of trees. Hence the "high o'er arching groves," and "the verdant portico of woods," of Milton and Thomson; Cowper says,

> ———" The grove receives us next,
> Between the upright shafts of whose tall elms," &c.

In Betchworth Park, Surrey, is an avenue of gigantic elms: its length is 350 yards, resembling the *nave of a cathedral;* the trees form, on the outside, a vast screen or wall of verdure; within, the branches, meeting at a great height in the air from the opposite rows, form "Gothic arches," and exclude every ray of the meridian sun.

Why does the arched form bear pressure so admirably?

Because, by means of it, the force that would destroy is made to compress all the atoms or parts at once, and nearly in the same degree. The whole substance of the arch therefore resists, almost like that of a straight pillar under weight, and is nearly as strong.

The strength of the arched form is exemplified in the well-known experiment of bottles, containing only air, and corked, being let down into the sea, and drawn up filled with water, and the cork driven in below the neck of the bottle. Thus, if the bottle have flat sides, and be square-bottomed, it will be broken by the pressure; but, if it be round, it will be more likely to resist the pressure, and have the cork forced in. The shape, in this case, is conducive to strength,—partaking of the qualities of an arch.

It is not known at what period the arch was invented, but it was comparatively in modern times. The hint was probably taken from nature; arched rocks being among the interesting wonders of the earth. At Lewis, in the Hebrides, is a stupendous specimen of curved gneiss, (a primitive rock, in which metals mostly abound) which has the bold symmetry of the Saxon arch. It is a matter of surprise, that, with so many specimens in nature, the arched form was not adopted earlier. The human skull is another specimen of the arched form; and the strength thus obtained, explains the unseeming impossibility of breaking an egg by pressing it endwise between our hands: again, what hard blows of the spoon or knife are often requisite to penetrate the shell. "The weakness of a similar substance, which has not the arched form, is seen in a scale from a piece of free-stone, which so readily crumbles between the fingers."

It is generally admitted, that the early Greeks were unacquainted with the principle of constructing the arch, and that neither the Indians nor Egyptians were acquainted with it. In Egypt, however, the monuments of which country are more ancient probably than any other on the face of the globe, the form of the Roman arch was well known, as is attested by remains of passages *cut out* in stone. Among the ruins of Thebes, sun-dried brick-buildings have been found to contain *constructed* arches, which may be referred to an age coeval with Thebes itself, as well as to any later period. In the oldest buildings of the Hairan, are round and pointed arches, cut out and constructed; so that the arch may be carried back to the earliest period at which these fertile plains were first peopled by a race dwelling in houses; and this we know to have been as early as the time of Job, or even before, as, in his day, his sons and daughters feasted luxuriously in *houses*. It is not, however, to be necessarily inferred from this, that the Romans borrowed the form of the arch, or the principle of its construction, from the East, since these might both have existed in this quarter at an early period, and yet have been discovered in Italy at a much later date, without any knowledge of its existence elsewhere.—*Abridged from Buckingham's Travels.*

Why is the invention of architecture attributed to the Egyptians?

Because the Egyptian capitals are a complication of orders in one mass, which, if divided, would produce numerous hints for new ideas. Thus, from the *lotus*-leaved capitals, it will be acknowledged, that the *Doric* and *Corinthian* orders have been extracted. The *Ionic*, also, is believed to have originated in Egypt; from the remains of the small temple of Isis, in the island of Philæ. Isis, is the Io of the Greeks, from whom the name of Ionic was no doubt derived; and it is very probable, that he who introduced the order gave it that name, as having been taken from the temple of the goddess. Such is the hypothesis of Belzoni, respecting three of the five orders; the remaining two are thus explained:—the *Tuscan*, by inspection, and comparison of its component elements, will be found almost the same as the Doric, and is evidently derived from it; and the *Composite* is formed of the proportions and enrichments of the Corinthian order, and the angular volute of the Ionic.

Why did the Egyptians erect such stupendous monuments as the pyramids?

Because, it is conjectured, of the policy of the

Egyptian rulers, whose plan to prevent the evils of over-populousness, was, to accustom the lower orders to a spare diet, and employ them in the construction of huge edifices, destined for tombs, or the temples of religion. Hence, the pyramids and excavated temples, which still excite the wonder of the world, and prove what may be effected by the aid of the simplest machinery,—with time, numbers, and perseverance.—*Belzoni.*

Why do the more ancient Egyptian monuments exceed the later in design and execution?

Because, among the Egyptians, every thing advanced to a certain point of perfection;—there stopped, never to advance, but rather to recede.—*Belzoni.*

Why are light-houses built of a circular form?

Because, partaking of the properties of the arch, it best enables them to withstand the fury of tempests, from every quarter. The Eddystone light-house, built by Mr. Smeaton, the English engineer, is a splendid triumph of this principle.

Why were mirrors first used for reflecting light-houses?

Because of the following trivial circumstance.

At a meeting of a society of mathematicians, at Liverpool, one of the members proposed to lay a wager, that he would read a paragraph of a newspaper, at ten yards distance, with the light of a farthing candle. The wager was laid, and the proposer covered the inside of a wooden dish with pieces of looking-glass, fastened in with glazier's putty,—placed his reflector behind the candle, and won his wager. One of the company marked this experiment with a philosophic eye. This was Capt. Hutchinson, the Dock-master, with whom originated the Reflecting Light-houses, erected at Liverpool, in 1763.

The revolving lights, as at Calais, are an improvement upon this invention. Lieutenant Drummond's ingenious application of ignited lime to the illumination of light-houses, a brilliant discovery of the present day, has been already noticed.*

Why is hempen-rope preferable to iron-chain for the scale of a weighing beam?

Because the rope resists a greater weight falling into the scale than is resisted by the chain, and is altogether stronger than the chain; the hemp yields by its elasticity, and continues its resistance through a considerable space and time,—and thus at last gradually overcomes the momentum; while the iron, by not yielding, either requires to be strong enough to stop the mass suddenly, or breaks.

Why are chain cables stronger than those of hemp or rope?

Because the chain, by its weight, hangs as a curve or inverted arch in the water, while the rope being nearly of the weight of water, is supported by it, and becomes almost a straight line from the anchor to the ship; and when a great wave dashes against the ship, the straight rope can only yield by the elasticity of its material, and, comparatively, therefore, a little way; but the bent chain will yield until it be drawn nearly straight, and by this greater latitude of yielding, and consequent length of resistance, it will stand a greater shock.—*Arnott.*

Why is British oak more durable than that of North America?

Because variable weather, as in Britain, conduces to firmness, whereas, the hot summers of North America impoverish its growth.

Why is steaming prejudicial to timber?

Because the heat and moisture together, always weaken that constituent principle of the timber, upon which its strength and durability in a great measure depend.

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* See POPULAR CHEMISTRY, page 50

Why is steaming indispensable for ship-building?

Because the planks cannot be otherwise curved or twisted, as in the bends of the hull of the vessel.

To give an idea of the enormous quantity of timber necessary to construct a ship of war, we may observe, that 2,000 tons, or 3,000 loads, are computed to be required for a seventy-four. Now, reckoning fifty oaks to the acre, of 100 years standing, and the quantity in each tree at a load and a half, it would require forty acres of oak-forest to build one seventy-four; and the quantity increases in a great ratio, for the largest class of line-of-battle-ships. A first-rate man-of-war requires about 60,000 cubic feet of timber, and uses 180,000 pounds of rough hemp, in the cordage and sails for it. The average duration of these vast machines, when employed, is computed to be fourteen years. It is supposed, that all the oaks now in Scotland, would not build two ships of the line. In Sweden, all the oak belongs to the king, or the proprietors of estates can only dispose of it to government; so that, when not wanted for the navy, it is often left to decay, and indeed, is generally much neglected.

Why is teak wood superior to oak?

Because it is stronger and more buoyant. Its durability is more decided; and, unlike the oak, it may be put in use almost green from the forest, without danger of wet or dry rot. The oak contains an acid which corrodes and destroys iron; the teak, on the contrary, possesses an essential oil which preserves iron.

Why are beech and elm good timber for the lower keels of ships, and the piles of bridges and harbours?

Because both, when under water, are extremely durable; though neither stand the effects of the atmosphere.

Why is fir preferable to oak for common building?

Because it is lighter, far more elastic, more easily worked, straighter, and of much greater length. The best that comes in the form of deals, is from Christiana and Frederickstadt, chiefly on account of the vast superiority of the saw-mills there.

Why was chestnut used in ancient roofs?

Because of its lightness and durability. The largest roof of the ancient construction is that of Westminster Hall, which is of chestnut. The support of every piece of timber is apparent; and the only strain which appears directly across the timber is on the boards and rafters between the great trusses; and it does not appear to be in the least decayed, although constructed four hundred and fifty years since.

COALS AND GUNPOWDER.

Why are coals so productive of grand mechanical effects?

Because of their great hidden powers, which we can at pleasure call into action. Thus, it is well known to modern engineers, that *there is virtue* in a bushel of coals, properly consumed, to raise seventy millions of pounds weight a foot high. This actually is the *average* effect of an engine at this moment working in Cornwall. The Menai Bridge, one of the most stupendous works of art that has been raised by man in modern ages, consists of a mass of iron not less than four millions of pounds in weight, suspended at a medium height of about 120 feet above the sea. The consumption of seven bushels of coal would suffice to raise it to the place where it hangs.

The great pyramid of Egypt is composed of granite. It is 700 feet in the side of its base, and 500 in perpendicular height, and stands on eleven acres of ground. Its weight is, therefore, 12,760 millions of pounds, at a medium height of 125 feet; consequently, it could be raised by the effort of about 630 chaldrons of coal, a quantity consumed in some foundries in a week.—*J. F. Herschel.*

Why is gunpowder another important source of mechanical power?

Because of the tremendous force which it exercises in certain operations, as blasting rocks, &c. in the progress of mechanical works. Thus, in the progress of cutting the Delaware Canal, four kegs of gunpowder, containing about 100lb. were, in 1829, used for a single blast, and had the effect of rending in pieces more than 400 cubic yards of rock.*

Yet it is only when we endeavour to confine gunpowder, that we get a full conception of the immense energy of that astonishing agent. In Count Rumford's experiments, twenty-eight grains of powder in a small cylindrical space *which was just filled*, tore asunder a piece of iron which would have resisted a strain of 400,000 pounds, applied at no greater mechanical disadvantage.

BALANCES.

Why are we enabled to determine the relative weight of a body, compared with the weight of another body, assumed as a standard, by means of the balance?

Because the balance consists of an inflexible rod or lever, called the beam, furnished with three axes; one, the fulcrum, or centre of motion. situated in the middle, upon which the beam turns, and the other two near the extremities, and at equal distances from the middle. These last are called the points of support, and serve to sustain the pairs or scales. These points and the fulcrum are in the same right line, and the centre of gravity of the whole should be a little below the fulcrum, when the position of the beam is horizontal. The arms of the lever being equal, it follows, that if equal weights be put into the scales, no effect will be produced on the position of the balance, and the beam will remain horizontal. If a small addition be made to the weight in one of the scales, the horizontality of the beams will be disturbed; and, after oscillating for some time, it will, on attaining a state of rest, form an angle with the horizon, the extent of which is a measure of the delicacy or sensibility of the balance.

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* By way of parallel with this effect, though produced by different means, we may mention that in 1825 there was opened in Cochin-China, a canal twenty-three miles long, eighty feet wide, and twelve feet deep. It was begun and finished in six weeks, although carried through large forests, and over extensive marshes. Twenty thousand men were at work upon it day and night; and it is said that seven thousand died of fatigue

Why should not the weights of a balance be touched by the hand?

Because that would not only oxydate the weight, (or cause it to rust) but by raising its temperature, it would appear lighter when placed in the scale-pan, than it should do, in consequence of the ascent of the heated air. For the large weights, a wooden fork or tongs should be employed; and for the smaller, a pair of forceps made of copper; this metal possessing sufficient elasticity to open the forceps on their being released from pressure, and yet not opposing a resistance sufficient to interfere with that delicacy of touch, which is desirable in such operations.—*Kater.*

Why does one weight alone serve to determine a great variety of others, by the steelyard?

Because the steelyard is a lever, having unequal arms, and by sliding the weight along the longer arm of the lever, we thus vary its distance from the fulcrum, taken in a reverse order; consequently, when a constant weight is used, and an equilibrium established, by sliding this weight on the longer arm of the lever, the relative weight of the substance weighed, to the constant weight, will be in the same proportion as the distance of the constant weight from the fulcrum is to the length of the shorter arm.

Why is the spring steelyard in very general use?

Because of its portability; as a spring that will ascertain weights from one pound to fifty, is contained in a cylinder only 4 inches long, and ¾ inch diameter. To use this instrument, the substance to be weighed is suspended by a hook, the instrument being held by a ring passing through the rod at the other end. The spring then suffers a compression, proportionate to the weight, and the number of pounds is indicated by the division on the rod, which is cut by the top of the cylindrical tube.—*Kater.*

The dial weighing machine is a modification of the same principle, connected with hands on a dial or clock-face to denote the weight.

WATER.

Why do water-wheels vary in their construction?

Because of the different ways in which the mechanical force of the liquid is intended to be applied.

Why are certain of these wheels called overshot?

Because the water by which they are impelled descends from its level to a lower one; its weight during the descent (falling, as it were, *over* the wheel) causing the wheel to turn. That this may be possible, it is only necessary that there should be a sufficient supply of water at the superior level, and that there should be a means of carrying it off after its descent, so as to prevent by its accumulation, the equalisation of the two levels. Hence the necessity of flood-gates in a mill course. On the circumference of the wheel the weight of the water is made to act in its descent, in a direction as nearly as possible at the right angles to the spokes, or radii; this pressure, however, acting only at one side of the wheel; thus making the wheel revolve, and communicate motion to its axis; and this motion being transmitted by wheel-work, and other contrivances, to the machinery which it is required to work.

Why are other wheels called undershot?

Because the flat or float boards placed at equal distances on the rim, and projecting from it, in directions diverging from its centre, are intended to receive the impulse of the water as it passes *under* the wheel. The wheel is thereby caused to revolve in the direction of the stream, with a force depending on the quantity and velocity of the water, and the number, form, and position of the float-boards.

The *breast* wheel partakes of the nature of the overshot and undershot wheels; like the latter, it has float-boards; but, like the former, it is worked more by the weight of water than by its impulse.

The *power of water* on wheels may be thus illustrated. If 100 gallons per minute be equal to a certain power with one foot of fall, one gallon per minute will perform the same work with 100 feet of fall.*

Why is the hydrostatic or Bramah's press, another example of the mechanical agency of water?

Because water, in common with all fluids, possesses the power of transmitting pressure equally in every direction. In this instance, too, it is materially aided by the mechanical efficacy of the lever.

Pascal demonstrated this principle and its advantages, by fixing to the upper end of a cask set upright, a very long and narrow cylinder. In filling the barrel, and afterwards the cylinder, the simple addition of a pint or two of water, which the latter was capable of containing, produced the same effect as if the cask, preserving its diameter throughout, had its height increased by the whole length of the cylinder. Thus, the increase of weight of a pint or two of water, was sufficient to burst the bottom of the hogshead, by the immense augmentation of pressure it occasioned. Now, if we suppose the water removed from the cylinder of narrow dimensions, and replaced by a solid of equivalent weight, such as a piston, it is evident that the pressure must remain everywhere the same. Again, if we suppose the weight of the piston to be multiplied by the power of a lever acting on its shaft, the pressure will be proportionally augmented, so as to produce on the bottom of the cask a pressure equivalent to an enormous weight, with the exertion of very little primitive force on the piston.—*Notes in Science.*

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* The mechanical force of running water is tremendous. During the great storm and flood in Scotland, in 1829, the river Don forced a mass of 400 or 500 tons of stones, many of 200 or 300 pounds weight, up an inclined plane, rising 6 feet in 8 or 10 yards. A stone of 3 or 4 tons, was likewise moved out of a deep pool of the river, 100 yards from its place.

This property of liquids also enables us with great facility to transmit the motion and force of one machine to another, in cases where local circumstances preclude the possibility of instituting any ordinary mechanical connexion between the two machines. Thus, merely by means of water-pipes, the force of a machine may be transmitted to any distance, and over inequalities of ground, or through any other obstructions.

Why is the hydrostatic press more advantageous than that worked by a screw?

Because between solids and fluids there is little or no friction; and, accordingly, in the hydrostatic press no force is lost by friction, except what is necessary to overcome the friction of the pistons in the cylinders. The loss of power in the screw, by means of friction, has already been explained at page 32.

ANIMAL STRENGTH.

Why does the rate of steam carriages surpass the utmost stretch of animal power?

Because the machine by which they are propelled, unlike any animal, rolls along unimpeded in any degree by the speed of its own motion.

According to some experiments, recently made by Mr. Bevan, to determine the actual force of draught of carriages upon common roads, it appears that five horses will draw with equal ease the same load upon a good hard turnpike road, as thirty-three horses can do upon loose sand. Or, if we assume the value of draught, upon a well-formed road in good condition, at 6*d.* per ton per mile, the equivalent price of draught will be upon hard turf, 7½*d.*; hard loam 9½*d.*; ordinary bye-road, 1*s.* 7*d.*; newly gravelled road, 2*s.* 2*d.*; loose sandy road, 3*s.* 1*d.*—*Philos. Mag.*

The power of some dogs is very extraordinary. Nine Esquimaux dogs, belonging to Captain Lyon, dragged 1611 pounds one mile (1760 yards) in nine minutes, and worked in this manner for seven or eight hours a day.

Why is it so disadvantageous to propel boats on canals by means of horses?

Because the expenditure of animal strength takes place in a far greater proportion than the increase of speed. Thus, if a horse of a certain strength is barely able to transport a given load ten miles a day for a continuance, two horses of the same strength will be altogether insufficient to transport the same load twenty miles a day. To accomplish that a greater number of similar horses would be requisite. If a still greater speed be attempted, the number of horses necessary to accomplish it would be increased in a prodigiously rapid proportion. This will be evident, if the extreme case be considered, viz., that there is a limit of speed which the horse, under no circumstances, can exceed. In an ordinary canal one horse with a boat will be sufficient for every thirty tons.

Why is a man better enabled than a horse to carry a weight up a steep hill?

Because the peculiar disposition of the limbs of a man, renders him well fitted for this species of labour; whereas it is the worst method in which a horse can be employed. It has been observed that three men climbing a hill, loaded with 100lbs. each, will ascend with greater speed than one horse carrying 300lbs.

The average value of human strength, considered as a mechanical agent, has been variously estimated. Desaguliers considers that a man can raise the weight of 550lbs. ten feet high in a minute, and continue to do so for six hours. Smeaton, however, thinks that six good English labourers will be required to raise 21,141 solid feet of sea-water to the height of four feet in four hours. In this case, they will raise very little more than six cubic feet of fresh water each, ten feet high in a minute. The labourers whom Smeaton supposes to execute this work he considers to be equal to twice the number of ordinary men. It would, therefore, perhaps, be a fair average value of a man's work to estimate it, for a continuance, at half a hogshead of water raised through ten feet in a minute.

The efforts of men differ with the manner in which these efforts are employed. It has been shown by Mr. R. Buchanan, that the same quantities of human labour employed in working a pump, turning a wheel, ringing a bell, and rowing a boat, are as the numbers 100, 167, 227, and 248. The most advantageous manner of applying human strength is in the art of rowing.—The strength of an ordinary man walking in an *horizontal* direction, and with his body inclining forward, is, however, only equal to 27lb., and it is known by experience, that a horse can draw *horizontally* as much as seven men.

Why is the power of a steam-engine expressed in horse power?

Because this mode was introduced when steam engines first began to supersede horse mills, when the manufacturer naturally inquired how many horses a steam-engine would dispense with. Hence the expression is more practical than scientific.

The power of a horse is understood to be that which will elevate a weight of 33,000* pounds, the height of one foot in a minute of time, equal to about 90 pounds at the rate of four miles an hour. This is a force greater than that exerted by a common cart horse, which is not estimated at more than 70 pounds: that is to say, that a horse harnessed to a cart, weighing, with its load, forty cwt. or two tons, and drawing on a level road at the rate of four miles an hour, makes use of the same force, as if his traces, instead of being fastened to a cart, were passed over a pulley, and lifted perpendicularly a weight of 70 pounds.

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* Another estimate reduces this to only 22,000 pounds, raised one foot high in a minute, equivalent to 100 pounds in two miles and a half per hour.

A steam-engine consumes about 20 feet of steam per minute for every horse-power.—*Notes in Science.*

RAILWAYS.

Why are railways more economical than ordinary roads?

Because, to drag a loaded waggon up one inconsiderable hill, costs more force than to send it thirty or forty miles along a level railway; and the conclusion follows, that although the original expense of forming the level line might materially exceed that of making an ordinary road, still, in situations of great traffic, the difference would soon be paid by the savings; and when once paid, the savings would be as profit ever after.—*Arnott.*

By way of illustrating the great economy of machinery, we may observe, that in Sedjah, (where the Arabs obtain fine millstones) "their unskilfulness and want of proper implements adapted to their labour, with the expense of carriage from the quarry to the place of sale, each stone requiring a single camel, (wheel carriages and good roads being entirely unknown) occasion an advance above the prime cost at which they might be hewn in England, of at least 500 per cent, each pair of stones costing from ten to twenty pounds sterling."—*Buckingham's Travels.*

Why has a suspension railway been represented as more advantageous than a ground railroad?

Because the former takes a straightforward point from one town to another, without regard to the surface of the country over which it has to go, whether rising or falling, a perfect level being obtained by varying the heights of the pillars or piers which support the railway; while its height above the ground allows agriculture and commerce to go on under it without interruption. The cost of a suspension railway has been estimated at £1,400 per mile, which is about two-thirds less than the average expense of a ground railroad. Models of a suspension railway, and carriages adapted to it, were recently exhibited in London, by Mr. Maxwell Dick, their inventor.

Why is wrought iron preferable to cast iron for railways?

Because by wrought iron rails we reduce the number of joints; the difficulty of making the rails perfectly even at the joints, has also contributed much towards the introduction of wrought iron.

Edge railways were first made of wood, near Newcastle; these were next covered with plates of wrought iron in the parts most likely to wear. Cast iron was subsequently introduced there and elsewhere; and wrought iron is now being very generally substituted for the cast.

Why has it been proposed to transfer the power of fixed and cheap first movers to locomotive carriages, &c. travelling on common turnpike roads?

Because the power of a steam-engine, moving with the locomotive carriage, is very expensive when compared to an equal power obtained by a large ordinary fixed engine, a wind or water mill, or other common first mover. Mr. Fordham, the originator of this plan, proposes to condense air into cylinders, and then to use this condensed air as the motive force.

Why has the application of steam to land carriages been so long a favourite project with mechanicians?

Because the transition from the one element to the other appears, at first view, to be so simple and easy: the same mechanical process which turns the paddle wheels of a vessel in the water, would seem quite adequate to impart a similar motion to the wheels of a carriage on land. So early as the year 1769, Mr. Watt mentions the practicability of applying it to domestic improvement, though it does not appear that Watt gave motion to a carriage. Symington, who claims the original invention of the steam-boat, had previously contrived a similar application for the impelling of carriages; and actually exhibited, in the year 1787, in Edinburgh, the first model of a steam-carriage that was perhaps ever seen. Hence we may conclude that the repeated failures in the plan have not been occasioned so much by the want of practical skill, as by some radical difficulty which had not been sufficiently adverted to.

The steepest inclined planes which, as far as we are aware, locomotive engines have attempted to surmount, are those on the Bolton and Leigh railway, in Lancashire. One of these planes is a mile and a half long, and rises one yard in thirty. Up the former of these the *Sans Pareil* engine ascended, drawing after her her tender carriage with coal and water, two waggons loaded with iron, and a carriage with passengers, making a gross weight drawn, of about fifteen tons; with which she moved at the rate of nine miles per hour. Up the steepest plane (rising 1 yard in 30) she drew her tender, and one carriage with passengers, the gross weight being about four tons fifteen cwt., with which she ascended at a speed of from nine to eleven miles per hour; each of these performances being equal to about sixty-five tons drawn on a level. —*Note to Quarterly Review.*

Why was the difficulty just adverted to greater in the land carriage than in the boat?

Because of the resistance to the progress of the carriage by the inequalities and other obstructions on the roads. It is not here as in navigation, where the most enormous weights are buoyed up by the liquid element, without increasing, in the same degree, the resistance to the vessel. Every additional load to a land carriage creates an additional resistance, arising from inertia, friction, and other such impediments, exactly in proportion to its weight.—*Quarterly Review.*

Why does the progress of locomotive engines on railroads appear so extraordinary?

Because we compare their moving power and resistance with other moving powers and resistances to which our minds have been familiar. To the power of a steam-engine, in fact, there is no practical limit; the size of the machine and the strength of the materials excepted. This is compared with agents to whose powers nature has not only imposed a limit, but a narrow one. The strength of animals, as just shown, is circumscribed, and their power of speed still more so.

Why are railways usually laid down in double lines?

Because carriages, moving in opposite directions, may pass each other without interfering. In the same manner, a third or fourth, or more lines, may be laid down, if necessary; and, between them are communications, at intervals, by which any carriage overtaking another in the same track, may turn aside to one of the adjacent lines, and pass it, without stopping either.

The Chevalier Baader, of Munich, has contrived a plan for this purpose, so that no siding planes nor turning plates are necessary; and turning can be performed almost as quickly and as easily as upon a common turnpike road. He has also constructed waggons, so that upon a dead level, the power of one horse is sufficient to draw with ease, and at a good pace, a load of from twelve to fourteen tons, when divided amongst several carriages linked together. The Chevalier also states that he has discovered a new principle, by which the power and motion of stationary steam-engines, and other machines, established at considerable distances apart, along the railroads, and working without interruption, can be imparted to any number of loaded carriages passing upon the railway, from one steam-engine or machine to another, without the employment of drag-ropes or chains, or, indeed, of any intermediate apparatus; and yet with any reasonable degree of velocity. These extraordinary statements are made in the *Franklin Journal*, 1830.

Why are the resistances which occur on a railway rather diminished than increased by velocity of motion?

Because the quicker we move along, there is the less time for the retarding force to operate; by increasing the rapidity, we escape, in some degree, from its influence, and may really be urged forward with a smaller amount of force, provided the machinery be adapted to so quick a rate of motion.—*Quarterly Review.*

Why has a tubular boiler, or one composed of welded iron pipes, been adopted by Mr. Gurney, in his steam carriage?

Because, even from the bursting of such a boiler, there is not the most distant chance of mischief to the passengers. Instead of being, as in ordinary cases, a large vessel closed on all sides, with the exception of the valves and steam conductors, which a high pressure or accidental defect may burst, Mr. Gurney's boiler consists of a horse-shoe of pipes, and the space between them is the furnace; the whole being enclosed with sheet-iron. The only possible accident would therefore be the bursting of one of these pipes, and a temporary diminution of the steam power, according to the proportion the pipe bears to the whole boiler.

Why were two steam cylinders introduced instead of one, in the early locomotive engines?

Because, by acting at different parts of the wheels, they produced a much more regular motion than formerly, and rendered unnecessary a fly-wheel, which had hitherto been used.

Why were the early engines so injurious to the railway?

Because of their enormous weight, amounting to six or eight tons, exclusive of the tender for water and fuel. The Rocket, lately constructed by Messrs. Stephenson and Co. of Newcastle-upon Tyne, weights only four tons five cwt.; and the Novelty, by Messrs. Braithwaite and Ericson, weighed but two tons fifteen cwt.

Why is a low chimney desirable, as in the Novelty engine?

Because it enables the proprietors of the railway to reduce the height of all the bridges under which the engines must pass, in crossing any of the public as well as private roads. It will admit of a deduction of seven or eight feet from the height of the mason-work in every such bridge. What a saving, then, must this produce in the original cost of a railway, through a cultivated country, where these bridges must frequently occur.—*Quarterly Review.*

Why is it no longer necessary to lay out railways on a perfect level?

Because engines have already been made to draw carriages up inclined planes rising one yard in thirty, and one yard in seventy-two, at the rate of from nine to eleven miles an hour. Hence we are enabled to vary the levels, and adapt them to the undulating nature of the country through which the line passes.

Why are steam carriages for the conveyance of goods, expected to improve the internal intercourse of this country in a very important degree?

Because it is calculated that the carriage of goods, which is now about 9*d.* or 10*d.* a ton per mile, by land, would thus be reduced to 2*d.*; and, in point of speed, one day would do the work of four. The heaviest commodities, such as corn, potatoes, coals, &c. would bear the expense of carriage for a hundred miles; the expense of living in great towns would be reduced, and the price of raw produce would rise in remote parts of the country.

Again, "with so great a facility and celerity of communication, the provincial towns of an empire would become so many suburbs of the metropolis, or rather, the effect would be similar to that of collecting the whole inhabitants into one city."—*Scotsman Newspaper.*

Another great source of revenue and of trade, from this improved mode of intercourse, (observes the *Quarterly Review*) would arise from the conveyance of those fine goods, parcels of value, and all light articles, where speed and certainty are required; and which are now sent, at great expense, by coaches. In this manner the seats of the various finer and lighter manufactures would be brought almost into immediate contact with the great markets for their disposal. A merchant in London, on receiving any particular order, might send either to Nottingham, to Birmingham, or to Sheffield, or even to Manchester or Leeds, and have the goods in his shop the next or following day, at an expense not exceeding 1*s.* 6*d.* or 2*s.*

Lastly, the rapid circulation of intelligence. The mails might travel safely at 25 miles an hour, and letters be conveyed between London and Edinburgh, a distance of 400 miles, in 18 hours; so that an event happening in London, would be known in Edinburgh the same day.

As an example of the difficulties of internal navigation, before the introduction of steam for that purpose, it may be mentioned that, on the great river Mississippi, which flows at the rate of five or six miles an hour, it was the practice of the boatmen, who brought down the produce of the interior to New Orleans, to break up their boats, sell the timber, and afterwards return home slowly by land; and a voyage up the river from New Orleans to Pittsburgh, a distance of about two thousand miles, could hardly be accomplished, with the most laborious efforts, within a period of four months. This voyage is now made by steam-boats, with ease, in 15 or 20 days; and at the rate of not less than five miles an hour.

Why would steam be advantageous for propelling ploughs and other agricultural implements?

Because, independently of the saving of horses and their food, the farmer would never be obliged to work his soil, but when it was in a proper condition for that purpose. Mr. Loudon thinks that to apply steam successfully to agriculture, the engineer ought not to seek for a new implement, but simply for a convenient locomotive power for propelling the implements already in use, modified so as to suit the new impelling power.

Why are the locomotive engines so advantageous for the conveyance of passengers?

Because they admit a rate of speed that would be entirely inconsistent with safety, even although it were practicable to attain it with animal power. It would be still imprudent, however, to adopt the utmost rate of thirty miles, because such an unusual rate of velocity, surpassing that of the swiftest horse, would be alarming, if it were not dangerous. At the rate of twenty miles an hour, however, it might be perfectly practicable to travel with the utmost safety and comfort. The economy of the plan may be illustrated as follows:—Between Liverpool and Manchester, we may safely estimate the number of passengers every day at 400 each way, and the average fare to be about seven shillings each; the daily expenditure will amount, in this manner, to about 280*l*. By the use of steam-coaches, the fares will be reduced to two-shillings and sixpence, and would thus amount only to 100*l.* per day, making a daily saving of 180*l.*, or upwards of 60,000*l.* per annum.

The expense of the Liverpool and Manchester Railway, is now estimated at upwards of 20,000*l.* for each mile; the whole cost amounting to 820,000*l.*

The rails used on the Liverpool and Manchester road are made of forged iron, in lengths of five yards each, and weigh thirty-five pounds per yard. Every three feet the rails rest on blocks of stone, let into the ground, containing each nearly four cubic feet. Into each block, two holes, six inches deep, and one inch in diameter, are drilled; into these are driven oak plugs, and the cast-iron chains or pedestals, into which the rails are immediately fitted, are firmly spiked down to the plugs, forming a structure of great solidity and strength. The double lines of rails for the carriages, are laid down with mathematical correctness, and consist of four equi-distant rails, four feet eight inches apart, about two inches in breadth, and rising about an inch above the surface. In the formation of the railway, there have been dug out of the different excavations, upwards of three millions of cubic yards of stone, clay, and soil.

THE STEAM-ENGINE.

Why is heat so important in the production of mechanical agents?

Because bodies, whether liquid, solid, or æriform, exert a certain degree of mechanical force, in the process of enlarging their dimensions, on receiving an accession of heat; and any obstacle which opposes this enlargement, sustains an equivalent pressure. This force is frequently used as a mechanical agent, and has this to recommend it, that it may be produced to almost any degree of intensity, without the expenditure of any other mechanical force in its production.

It is not requisite to enter theoretically into the production of heat, since the subject has already been popularly illustrated in the present work.*

Why is the steam-engine much more intelligible than its name first suggests?

Because it is in fact only a pump, in which the fluid is made to impel the piston, instead of being impelled by it, that is to say, in which the fluid acts as the *power*, instead of being the *resistance*. It may be described simply as a strong barrel or cylinder, with a closely filled piston in it, which is driven up and down by steam, admitted alternately above and below from a suitable boiler; while the end of the piston-rod, at which the whole force may be considered as concentrated, is connected in any convenient way with the work that is to be performed. The power of the engine is of course proportioned to the size or area of the piston, on which the steam acts with a force, according to the density, of from 15 to 100 or more pounds to each square inch. In some of the Cornish mines, there are cylinders and pistons of more than 90 inches in diameter, on which the pressure of the steam equals the efforts of 600 horses.—*Arnott.*

The steam-engines in England represent the power of 320,000 horses, equal to 1,920,000 men, and being, in fact, managed by only 36,000 men, add consequently to the power of our population, 1,884,000 men.

The cost of a steam-engine varies according to its power. The smaller cost nearly 100*l.*, for each horse power, the largest not quite 400*l.* The consumption of coal is rated at one bushel, or 84 pounds per hour, for an engine of ten-horse power; the quantity is somewhat less in proportion in engines of great power.

Why is there a large vibrating beam in the steam-engine?

Because, one end being connected with the piston-rod, is pulled down, while the power of the engine is applied at the other end to any mechanical purpose. Thus, when connected with immense water-pumps, it causes almost a river of water to gush out from the bowels of the earth.

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* See Part V., CHEMISTRY.—*Heat*, p. 21 to 35.

Why are the improved paddle-wheels of steam-boats made to enter the water sideways?

Because they give the propelling stroke direct, whereas the ordinary wheels press the broad face of their paddles on the surface of the water, and thus increase the resistance.

Why are steam-engines of such important use in mining?

Because they speedily raise the water which breaks in on the miners.

The practical adaptation of the steam-engine to mechanical purposes, is considered by Mr. Davies Gilbert as due to Mr. Newcomen, whose inquiries were introduced into Cornwall very early in the last century, and soon superseded the rude machinery which had, till then, been employed for raising water from mines, by the labour of men and horses.

The various applications of steam-power would occupy many pages: if we except its adaptation to the motion of carriages, perhaps few of its effects are more astounding than in the manufacture of iron. Thus, there are factories where this resistless power is seen, with its mechanic claws, seizing masses of iron, and in a few minutes delivering them out again pressed into thin sheets, or cut into bars and ribands, as if the iron had become soft, like clay in the hands of the potter.

The annual product of the foundries of Messrs. Crawshay and Co. in Glamorganshire, is 11,000 tons weight of pig-iron, and 12,000 tons of iron in bars. A steam-engine of the power of 50 horses, and a water-wheel of 50 feet diameter, work the cylindrical blowing-machines, which are indispensably necessary in the use of coke, and the other machinery of the works. This enormous water-wheel is kept in motion by the pressure of 25 tons of water per minute. The establishment employs from 1,500 to 2,000 workmen, forming, with their families, a population of 4,000 persons. The sum total of their wages amounts annually to from 70,000*l.* to 80,000*l.*

Such has been the progressive improvement in the steam-engine, that in 1829, the best engine in Cornwall did ten times the work of any engine in 1778; or each bushel of coals raised 20,000 gallons of water.

M. Dupin estimates the steam-engines of France equivalent to the power of 480,000 workmen turning a winch; and it is calculated by the same writer, that Great Britain possesses, in steam-engines alone, a moving power equivalent to that of 6,400,000 men employed at the windlass.

Why do high pressure differ from low pressure engines?

Because, in high pressure engines the steam is not condensed; but after having acted on the piston, is allowed to blow off into the air; whereas, in low pressure engines it passes into a separate vessel, where it is condensed; on which account, and for other reasons, low pressure engines do not suit a rail-road. High pressure engines occupy less room, require less fuel than low pressure engines, and their power can be increased on emergencies, by merely increasing the fire; but the risk of damage from explosion is considerable. Their principal purpose is to save water, but this is always abundant in navigation.

The principle of high pressure steam-engines depends on the power of steam to expand itself, 5, 10, 20, 30, 40, &c. times beyond its original bulk, by the addition of a given portion of heat, which is effected by increasing the pressure.

Under mean pressure, at the temperature of 212°. (the boiling point) the bulk of steam is 1,800 times that of water; or, as a ready rule for calculation, a cubic inch of water produces about a cubic foot of steam. The latent heat of steam is about 960°.

Why is Brown's Pneumatic Engine a species of steam-engine?

Because its principle is a very sudden expansion and condensation, not of the gases used in the operation, but of the small quantity of water formed by the combustion of the hydrogen, with the oxygen of the atmospheric air, admitted into the cylinder at every stroke of the engine. The difference between this and a steam engine is, that the elastic and condensable fluid is generated at a higher temperature from materials admitted into the cylinder itself. The extent of the vacuum produced must depend on the temperature at which the combustion takes place.—*Notes in Science.*

Why is the explosive engine so called?

Because it is set in motion by the explosion of oil gas and atmospheric air, the mechanical force of the explosion being employed to drive the machinery. Percussion powder, and other substances that explode by contact, may eventually be employed for the same purpose.

RECENT INVENTIONS AND IMPROVEMENTS.

Why is the printing-press invented by Lord Stanhope so superior to the wooden press, or that previously in use?

Because the Stanhope press is composed entirely of iron; the table on which the types rest, and the platten (or surface which gives the impression) are made perfectly level; a beautiful combination of levers is added, to give motion to the screw, causing the platten to descend with increasing rapidity, and consequently with increasing force, till it reaches the type, when a very great power is obtained. There have been, perhaps, twenty contrivances for obtaining the same effect; but, as *a press*, Lord Stanhope's invention has not been surpassed. Still, it is only a press, and in point of *expedition* has little superiority over its wooden rival, producing 250 impressions per hour.

It is a remarkable fact, that from the invention of printing to the year 1798, a period of nearly three hundred years, no improvement had been introduced into this important art.*

A mere outline of the improvements from this period would occupy many pages. The great triumph in the art has, however, been the substitution of cylindrical machinery for the screw-press. The *suggestion* of this improvement belongs to Mr. W. Nicholson, but the two first *working* machines were erected by Mr. Koenig, for printing the *Times* newspaper, the reader of which was told, on Nov. 28, 1814, that he held in his hand a newspaper printed by machinery, and by the power of steam!

In these machines the type was made to pass under the cylinder, on which was wrapped the sheet of paper, the paper being firmly held to the cylinder by means of tapes; the ink was placed in a cylindrical box, from which it was forced by means of a powerful screw depressing a tightly-fitted piston; thence it fell between two iron rollers; below these were placed a number of other rollers, two of which had, in addition to their rotatory motion, an end motion, *i. e.* a motion in the direction of their length; the whole system of rollers terminated in two, which applied the ink to the types. In order to obtain a great number of impressions from the same form, a paper cylinder (*i. e.* the cylinder on which the paper is wrapped) was placed on each side the inking apparatus, the form passing under both. This machine produced 1,100 impressions per hour; subsequent improvements raised them to 1,800 per hour.

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* Mr. Buckingham saw in a convent on the mountains of Lebanon, a printing-press and Syriac types, from which the monks produce their church-books, quite equal to those at Rome. The press nearly resembled in shape the common printing-press used in England. It is there considered a mystery, as "they had never yet had an European here, who had ever seen the mechanical operation of printing in Europe." Other monks in the same convent were employed in weaving, masonry, carpentry, &c.

The next machine, also by Mr. Koenig, was for printing both sides of the sheet, by conveying the sheet from one paper cylinder to the other. This was made in 1815, and printed 750 sheets on both sides per hour. In the same year Mr. Cowper obtained a patent for curving stereotype plates, for fixing them on a cylinder. Several of these machines, capable of printing 1,000 sheets per hour on both sides, are at work at the present day; and twelve machines on this principle were made for the Bank of England, a short time previous to the recent issue of gold. These machines, though only adapted for stereotype printing, first showed the best method of furnishing, distributing, and applying the ink by rollers.

Messrs. Applegath and Cowper have, however, by their conjoint ingenuity, superseded Mr. Koenig's inventions, and constructed upwards of 60 machines, modified in twenty-five different ways, for printing books, bank-notes, newspapers, &c.: their greatest success has been in printing newspapers. In the *Times* machine, which was planned by Mr. Applegath, the form passes under four printing cylinders, which are fed with sheets of paper by four lads, and after the sheets are printed, they pass into the hands of four other lads; by this contrivance 4,000 sheets per hour are printed on one side.

The comparative produce of the above machines is as follows:—

Stanhope press - - -	250 impressions per hour.
Koenig's machine - - -	1,800 *i. e.* 900 on both sides
Cowper's (stereotype) - -	2,400 *i. e.* 1,200 ditto.
Applegath and Cowper's (book)	2,000 *i. e.* 1,000 ditto.
Ditto (newspaper) Chronicle -	2,000
Herald -	2,400
Times -	4,000—66 per minute

We have principally abridged these facts and data from a valuable paper communicated by Mr. Cowper, one of the inventors, to the Royal Institution, and subsequently to the *Quarterly Journal of Science*, in the year 1828.

The machine for printing the *Atlas* newspaper, (each copy of which, in some cases, has contained 40 feet of printed superficies) consists of two larger and two lesser cylinders, put in motion by a steam-engine of 4-horse power, managed by three boys, whose only task is to present the end of the enormous blank sheet to the first cylinder, and to receive it, in a few seconds, printed on both sides, as it is discharged by the last cylinder.

Why will some machines produce paper of indefinite length?

Because in them the pulp is delivered from the trough to an endless web of wire, passing over cylinders, which are turned by steam, or any other prime mover. From the wire web it passes between two rollers to an endless web of felt, which passes over other cylinders, and between two other heavy rollers, for the expression of the water; the paper is thence wound upon a reel, and when a sufficient quantity is received on it, the paper is cut off, and removed to the drying-house. At White Hall Mill, in Derbyshire, a sheet of paper was lately manufactured which measured 13,800 feet in length, 4 feet in width, and would cover an acre and a half of ground.

Why does beating books with a hammer cause the printing to "set off" on the opposite page?

Because the blows suddenly compress the air between the leaves, and create heat which disturbs the ink.

Why has pressing been advantageously substituted for this beating?

Because it renders the books extremely compact and solid, by passing the sheets, when folded, between a pair of powerful rollers, by which much time is saved, the paper is made smoother, and the compression, though greater, does not disturb the ink. A rolled book will thus be reduced to about five-sixths of the thickness of the same book, if beaten: a shelf, therefore, that will hold fifty books beaten in the usual manner, will hold nearly sixty of such, if rolled.—*Trans. Soc. Arts.*

Why are knives sharpened by being drawn between two horizontal rollers, as in "the patent knife-sharpener?"

Because the rollers revolve freely upon their axis; and at uniform distances are fixed narrow cylinders, or rings of steel, the edges of which are finely cut with file teeth, forming thereby circular files; the edges of these files overlap or intersect each other a little, so that when a knife is drawn between them, it operates on both sides of the edge at once; and as the rollers turn round at the slightest impulse, the peripheries of the circular files get uniformly worn, and consequently will last a long time.

Why does the transparent dial of St. Giles's church, London, light itself with gas as soon as the sun sets at night, and put out the light when the sun rises in the morning?

Because a wheel is connected with the clock, which makes but one revolution in twenty-four hours; and on this is placed a series of pins, which, by their revolution with the wheel, tend to raise a lever connected both with a gas-cock and a movable screen. The gas which illuminates the dial is burning at all times, but the consumption during the day is comparatively small, as the lever opens and shuts the aperture by the motion of the large wheel; so that a person in the immediate neighbourhood of the clock would see little more than a faint indication of flame during the day light; but at evening the lever opens the aperture to its full size, and lets forth a brilliant flame. The movable screen completely cuts off any portion of light which might otherwise pass from the partially closed burner.—*Mr. C. F. Partington, in the Atlas Newspaper.*

Why are the faces of many new public clocks made of stone instead of metal?

Because stone being an absorbent, and not so good a conductor of heat as metal, the paint adheres better and lasts longer, and does not require to be renewed so often as on the copper dial. Another advantage of the stone dial is, that the centre can be sunk, and the hour hand made to traverse in the sinking. This enables the minute-hand to be close to the figures, and then almost all error from the effect of parallax is avoided, which in the copper dial is very considerable; especially when the minute-hand points at or near 15 and 45 minutes, and the hands are both above the dial. In the stone dials of Chelsea new church, and the Royal Mews, Pimlico, the figures are cut in the stone, and sunk about the eighth of an inch, after the manner of the Egyptian monuments, from which was derived the idea. By this method, supposing the dial accurately divided, and the figures well shaped in the first instance, they will always remain so.—*Mec. Mag.*

The originator of this improvement is Mr. Vulliamy, the eminent horologist.

Why is the Diorama so called?

Because of its origin from the Greek, signifying two views, of which this exhibition consists. These pictures are painted in solid, and in transparency, arranged and lighted in a peculiar manner, so as to exhibit changes of light and shade, and a variety of natural phenomena. The means by which these changes are effected, may be explained as follows:—The contrivance is partly optical, partly mechanical; and consists in placing the pictures within a building so constructed, that the saloon containing the spectators may revolve at intervals, for the purpose of bringing in succession two distinct pictures into the field of view, without the necessity of the spectators removing from their seats; while the scenery itself remains stationary, and the pictures therefore admit of an improved method of distributing light, by which they are illuminated, so as to produce the effects of a variable picture. This is performed by means of a number of transparent and movable blinds, some of which are placed behind the picture for the purpose of intercepting and changing the colour of the rays of light, which are permitted to pass through the semi-transparent parts of the picture. Similar blinds are also situated above and in front of the pictures, so as to be movable by the aid of cords, and by that means to distribute or direct the rays of light which are permitted to fall upon the front of the scene.

The extent of revolving motion given to the saloon, is an arc of about 73°; and during the time that the audience is thus passing round, no person is permitted to go in or out. The revolution of the saloon is effected by means of a sector, or portion of a wheel, having teeth formed upon its edge; these work in a series of wheels and pinions, so that one man placed at a winch is enabled to give motion to the whole.

The space between the saloon and each of the two pictures is occupied on either side by a partition, forming a kind of avenue, proportioned in width to the size of the picture; without such a precaution, the eye of the spectator being thirty or forty feet distant from the canvass, would, by any thing intervening, be estranged from the object. The views are eighty-six feet in length and forty-five feet in height.—*Atlas.*

END OF PART VII

KNOWLEDGE FOR THE PEOPLE:

OR THE

PLAIN WHY AND BECAUSE.

PART X.—ARTS AND MANUFACTURES.

ARTS AND MANUFACTURES.

INTRODUCTORY.

Why have commerce and the arts an indirect influence upon industry?

Because it signifies nothing as to the main purposes of trade, how superfluous the articles which it furnishes are;—whether the want of them be real or imaginary: —whether it be founded in nature or in opinion, in fashion, habit, or emulation;—it is enough that they be actually desired and sought after. Flourishing cities are raised and supported by trading in tobacco; populous towns subsist by the manufactory of ribands. A watch may be a very unnecessary appendage to the dress of a peasant, yet if the peasant will till the ground in order to obtain the watch, the true design of trade is answered; and the watchmaker, while he polishes the case, or files the wheel of his machine, is contributing to the production of corn as effectually, though not so directly, as if he handled the spade or held the plough. Tobacco is an acknowledged superfluity, and affords a remarkable instance of the caprice of human appetite; yet, if the fisherman will ply his net, or the mariner fetch rice from other countries, in order to procure to himself this indulgence, the market is supplied with two important articles of provision, by the instrumentality of a merchandise which has no other apparent use than the gratification of a vitiated palate.*—*Paley.*

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* We should here remark however, that where false refinement, or a corrupted taste, engages that time and ingenuity of the laborer or the artist, which might otherwise have produced articles that contribute to rational enjoyment, it is an evident *misapplication* of industry.

Why does commerce at the same time supply an endless variety of new productions, and multiply and cheapen those that are peculiar to every country?

Because it enables each separate people to employ themselves in preference in those departments in which they enjoy some natural or acquired advantage, while it opens the markets of the world to their productions. When the demand for a commodity is confined to a particular country, as soon as it is supplied, improvement is at a stand. The subdivision and combination of employments are, in fact, always dependent upon, and regulated by, the extent of the market. Dr. Smith has shown, that by making a proper distribution of labour among ten workmen, in a pin manufactory, 48,000 pins might be produced in a day; and since his time the number has been nearly doubled.

Before pins were manufactured in England, £60,000 annually is said to have been paid for them to foreigners in the early years of Queen Elizabeth; but, long before the end of her reign, they were manufactured in this country in great quantities.

The subdivision of the mechanism of a watch into 150 branches has already been cursorily mentioned.* The fifteen principal branches are: 1. The movement maker, who divides it into various branches; viz. pillar-maker, stop stud-maker, frame-mounter, screw-maker, cock and potence-maker, verge-maker, pinion-maker, balance-wheel-maker, wheel-cutter, fusee-maker, and other small branches. 2. Dial-maker; who employs a copper-maker, an enameller, painter, &c. 3. Case-maker; who makes the case to the frame, employs box-maker, outside case-maker, and joint-finishers. 4. Pendant-maker; (both case and pendant are sent to the Goldsmiths' Hall to be marked.) 5. Secret-springer and spring-liner; the spring and liner are divided into other branches; viz. the spring-maker, button-maker, &c. 6. Cap-maker, who employs the springer, &c. 7. Jeweller, which comprises the diamond-cutting, setting, making ruby-holes, &c. 8. Motion-maker, and other branches, viz. slide-maker, edge-maker, and bolt-maker. 9. Spring-maker, (i. e. main-spring) consisting of wire-drawer, &c. hammerer, polisher, and temperer. 10. Chain-maker; this comprises several branches, wire-drawer, link-maker and rivetter, hook-maker, &c. 11. Engraver; who also employs a piercer and name-cutter. 12. Finisher, who employs a wheel and fusee-cutter, and other workers in smaller branches. 13. Gilder is divided into two, viz. gilder and brusher. 14. Glass and hands; the glass employs two, viz. blower and maker: hand-maker employs die-sinker, finisher, &c. 15. Fitter-in, who overlooks the whole, fits hands on, &c. The above fifteen branches are subdivided again and again.

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* See DOMESTIC SCIENCE page 71.

The manufacture of watch-springs also affords an instance of an article raised in price from one halfpenny to the amount of 35,000 guineas. Thus, a pound of crude iron costs one halfpenny; it is converted into steel, that steel into watch-springs, every one of which is sold for half-a-guinea, and weighs only one-tenth of a grain. After deducting for waste, there are, in a pound weight, 7,000 grains; it therefore affords steel for 70,000 watch-springs, the value of which, at half-a-guinea each, is 35,000 guineas.

Why may our cotton manufacture be considered entirely the result of commerce?

Because, had cotton-wool been a native production, we could never have made such astonishing advances in the manufacture had we been denied access to foreign markets. Notwithstanding the splendid discoveries in the machinery, and the perfection to which every department of the trade has been brought, the vast extent of the market has prevented its being glutted; and has stimulated our manufacturers in their improvements. Our cotton-mills have been constructed, not that they might supply the limited demand of Great Britain, but that they might supply the demand of the whole world. The subdivision of labour, and the scope given to the employment of machinery, by the unlimited extent of the market, has reduced the price of cottons to less, probably, than a fourth part of what it would have been, had they met with no outlet in foreign countries.* The hardware, woollen, leather, and other manufactures, exhibit similar results.

Why is steam said to add to the power of our population?

Because the steam-engines in England represent the power of 320,000 horses, equal to 1,920,000 men; and being in fact managed by only 36,000 men, they consequently add to the power of our population 1,884,000 men.

Steam navigation, a powerful aid to our commercial prosperity, has been thus eloquently illustrated by one of the most accomplished orators of our times. Steamboats—"these new and wonderful machines walk the water, like a giant rejoicing in his course; stemming alike the tempest and the tide; accelerating intercourse; shortening distances; creating, as it were, unexpected neighbourhoods, and new combinations of social and commercial relations; and giving to the fickleness of winds and the faithlessness of waves, the certainty and steadiness of a highway upon the land."—*Canning's Speeches at Liverpool.*

According to M. Dupin, the human force of Great Britain employed in commerce and manufactures, is equivalent to 4,264,000,893 effective men; to this power there must also be added the power of 250,000 animals, employed in divers works of industry. These will raise the animate force of England and Scotland to 6,014,893; to which there must be superadded the approximating value of 1,260,604 effective men for Ireland: so that the commercial and manufacturing animate power of the United Kingdom must be computed at 7,275,497 labouring men. To this must be added the force supplied by water, wind, and steam: thus:—

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* The price of calico 55 years since has been found thus registered in a bible, in the possession of a family near Blackburn:—"15 September, 1776. Thomas Dixbury, of Rishton, near Blackburn, sold to Messrs. Peels, Yates, and Co. Church Bank, two common fine calico pieces for 5*l*. 9*s*. 8*d*. These were the first calico pieces ever manufactured in this kingdom." Pieces of the same description are now so for 5*s*. 6*d*. or 6*s*. each.—*Mechanics Magazine.*

	Men power.
Animate Force - - - - - -	7,275,497
Mills and Hydraulic Engines - -	1,200,000
Windmills - - - - - - -	240,000
Wind and Navigation - - - - -	12,000,000
Steam Engines - - - - - -	6,400,000
Total Force - - - - -	27,115,497
Ireland - - - - - -	1,002,667
Total - - - -	28,118,164

In comparison with France, M. Dupin estimates these numbers as follows:—The total of the inanimate force applied to the arts, of all descriptions, in France, scarcely exceeds the fourth of the same power applied to the same purposes in Great Britain; and the whole animate and inanimate power of Great Britain, applied to manufactures and commerce, is nearly triple the amount of that so applied in France.

Why is foreign trade so beneficial to each party engaged in it?

Because each enjoys the peculiar advantages of the respective countries. Thus, when we send cloth or hardware to Portugal for wine, or to Brazil for sugar, we give what is as valuable as that which we receive; and yet both parties gain largely by the transaction; for we get the wine and sugar for what it took to produce them in countries that are peculiarly fitted for their growth; and the foreigners are supplied with cloth and hardware for what those productions cost in a country where manufacturing industry has been carried to the highest pitch of improvement.

M. Say, in his *Economie Politique Pratique*, thus forcibly illustrates the effects of prohibition in trade. During the reign of Napoleon, vessels were despatched from London, freighted with sugar, coffee, tobacco, cotton-twist, for Salonica, (Macedonia) whence these articles of merchandise were carried by beasts of burden, by the way of Servia and Hungary, to Germany and France; so that an article consumed at Calais, would come from England, only twenty miles distant, by a route which, in point of expense, would be equivalent to a voyage twice round the globe.

Again, the history of our own times affords many striking instances of the prohibitory effects of war upon national industry. In France, the ravages made by the wars of the revolution and of the empire upon her population and wealth, have been estimated, according to M. Dupin, at two millions of men, and 600 millions of English money. Every succeeding year of peace, from 1815 to 1830, has, however, healed these severe wounds; private losses have been indemnified; houses and factories have been rebuilt; the cattle and live stock become more numerous than before the war, and the population increased, in thirteen years, by two millions and a half of inhabitants. As an example of the beneficial effects upon manufacturing industry; it is only since the reestablishment of their intercourse with England, that the French have begun to use pitcoal in their furnaces, and to substitute the instrument called a flattener, or *laminoir*, for the hammer, in beating iron into plates.

Why are certain natural advantages in a country prejudicial to its progress in the arts?

Because, provided the mildness of the climate renders clothing and lodging of little importance, and th earth spontaneously pours forth an abundant supply of fruits, the inhabitants are immersed in sloth, and seem to place their highest enjoyment in being free from occupation. Sir William Temple, Mr. Hume, and some other sagacious inquirers into the progress of society, have been struck with this circumstance, and have justly remarked that those nations that have laboured under the greatest natural disadvantages, have made the most rapid advances in industry. A striking illustration of the above fact follows.

Why has the improvement of the natives of South America been so tardy?

Because of the extraordinary abundance of animal food, and the equal fertility of the country, where the finest fruits grow spontaneously, and only require to be gathered. Thus, the South Americans are neither a pastoral nor an agricultural people; and, surrounded by partial civilisation, they remain without any excitement to labour, which alone could improve their moral and physical condition. Humboldt has thus beautifully described the state of primitive rudeness in which many of the tribes of South America remain: "When we attentively examine this wild part of America, we appear to be carried back to the first ages, when the earth was peopled step by step; we seem to assist at the birth of human societies. In the Old World we behold the pastoral life prepare a people of huntsmen for the agricultural life. In the New World we look in vain for these progressive developements of civilisation—these moments of repose—these resting-places in the life of a people. The luxury of vegetation embarrasses the Indian in the chase. As the rivers are like arms of the sea, the depth of the water, for many months, prevents their fishing. Those species of ruminating animals, which constitute the riches of the people of the Old World, are wanting in the New. The bison and the musk-ox have not yet been reduced to the domestic state; the enormous multiplication of the lama and the guanaco have not produced in the natives habits of pastoral life."

Why has the coin of a kingdom been compared to the highways through it?

Because neither of them produce any thing; on the contrary, they are both to be kept in repair at a certain expense; but they greatly facilitate the conveyance from one place to another, of whatever the land produces by agriculture, or what active capital produces by manufactures and commerce. Such is the idea of Dr. Adam Smith, who also compares paper-money to a wagon-way through the air.

Why are we indebted to the ignorance and bad government of our ancestors for our present comparative facility of procuring subsistence?

Because, had it been otherwise, the population that would have accumulated since the reign of William the Conqueror, must have overflowed, like the swarming of the northern hives during the fall of the Roman empire. An entertaining writer says: "If all the Turks and Egyptians that are to die next year of the plague, were to be devoured during the present by crocodiles, a certain quantity of food would be gained, and things go on just as before. The Roman empire, and the world generally, would have been equally populous and prosperous, if the Huns and Ostrogoths had eaten each other, instead of strewing their bones and those of their antagonists through the wilds of Dacia and along the banks of the Danube."

Why is it an error to consider Apothecaries' profits uncommonly extravagant?

Because this great apparent profit is frequently no more than the wages of labour. The skill of an apothecary is a much nicer and more delicate matter than that of any artificer whatever; and the trust which is reposed in him, is of much greater importance. He is the physician of the poor in all cases, and of the rich, where the distress or danger is not very great. His reward, therefore, ought to be suitable to his skill and his trust, and it arises generally from the price at which he sells his drugs. But the whole drugs which the best employed apothecary in a large market-town will sell in a year, may not, perhaps, cost him above thirty or forty pounds. Though he should sell them, therefore, for three or four hundred, or at a thousand per cent. profit, this may frequently be no more than the reasonable wages of his labour, charged, in the only way in which he can charge them, upon the price of his drugs: the greater part of the apparent profit is real wages disguised in the garb of profit.—*Dr. Adam Smith's Wealth of Nations.*

WEIGHTS AND MEASURES.

Why do we use the grain weight?

Because all weights and measures in England were originally derived from a *grain of wheat:* vide statutes 51 Hen. III. 31 Ed. I. 12 Hen. VII. which enacted that 32 of them, well dried and gathered from the middle of the ear, were to make one penny-weight; but it was subsequently thought better to divide the dwt. into twenty-four equal parts, called *grains.* All measures of capacity, both liquid and dry, were at first taken from troy-weight; and laws were passed in the reign of Henry III. enacting that 8lb. troy of wheat taken from the middle of the ear, and well dried, should make one gallon of wine measure. Weights and measures were invented 869, B. C.; fixed to a standard in England, 1257; regulated, 1492; equalized, 1826.

Why has the pendulum been resorted to in regulating modern weights and measures?

Because it has enabled us practically to carry into effect the idea of seeking for a unit of measure in some unchangeable natural object; the great law of the pendulum being, that its oscillations are always performed in the same time. The standards that have been usually proposed for the above purpose, have been some aliquot part of the quadrant of the meridian, or the length of a pendulum vibrating seconds in some given latitude. The latter has been in so far adopted into the existing system of weights and measures, established by the Act of Parliament of 1824, that the length of the standard yard, as compared with that of a pendulum vibrating seconds in the latitude of London, is determined to be in the proportion of 36 inches to 39 $\frac{1393}{10000}$ inches.

The pendulum, as a time-keeper, has been mentioned in another portion of the present work.*

Why are the foot, yard, &c. used as measures?

Because the earliest standards seem to have been for the most part derived from portions of the human body: as the cubit, or the length of the arm from the elbow to the tip of the middle finger; the foot; the *ulna*, arm, or yard; the span; the digit, or finger; the fathom, or space from the extremity of the one hand to the extremity of the other, when they are both extended in opposite directions; the pace, &c. These were not, however, *fixed* standards, as the size of the different parts of the human body differ in different individuals: hence it became necessary to select some durable article, a metallic rod, for example, of the length of an average foot, cubit, &c. and to make it the standard with which all the other feet, cubits, &c. used in mensuration, should correspond. These standards have been preserved with the greatest care; at Rome they were kept in the temple of Jupiter; and among the Jews, their custody was entrusted to the family of Aaron.

This standard has been maintained without any sensible variation. In 1742, the Royal Society had a yard made, from a very careful comparison of the standard ells or yards of the reigns of Henry VII. and Elizabeth, kept at the Exchequer. In 1758, an exact copy was made of the Royal Society's yard; and this copy having been examined by a Committee of the House of Commons, and reported by them to be equal to the standard yard, it was marked as such: this identical yard is declared, by the Act 5 Geo. IV. cap. 74, to be the standard of lineal measure in Great Britain.

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* See MECHANICS, p. 14-15.

Without entering into standards of an abstract kind, we may here observe, that "a real material measure must be constructed, and exact copies of it taken. The great difficulty is, however, to preserve it unaltered from age to age; for unless we transmit to posterity the units of our measurements, *such as we have ourselves used them*, we, in fact, only half bequeath to them our observations." Mr. J. F. Herschel thinks this point much neglected, and suggests that "accurate and *perfectly* authentic copies of the yard and pound, executed in platinum, and hermetically sealed in glass, should be deposited deep in the interior of the massive stone-work of some great public building, whence they could only be rescued with a degree of difficulty sufficient to preclude their being disturbed, unless on some very high and urgent occasion. The fact should be publicly recorded, and its memory preserved by an inscription. Indeed, how much valuable and useful information of the actual existing state of arts and knowledge at any period might be transmitted to posterity in a distinct form, if, instead of the absurd and useless deposition of a few coins and medals under the foundations of buildings, specimens of ingenious implements, or condensed statements of scientific truths, or processes in arts and manufactures were substituted."

MONEY.

Why is the term standard used?

Because it may designate the purity and weight of coins; that is, the fineness of the metal of which they are made, and the quantity of it contained in them.

Money was coined in the Temple of Juno *Moneta*, whence our English word *money*, and the *monetary* of political economists.

A pound troy, or 12 oz. of the metal of which English silver coins are made, contains 11 oz. 2 dwts. pure silver, and 18 dwts. alloy. This pound is coined into 66 shillings, so that each shilling contains 80.727 grains of fine silver, and 87.27 grains of standard silver; and the *money pound*, consisting of 20 shillings, contains 1614.545 grains standard silver. From 1600 down to 1816, the pound weight of standard silver bullion was coined into 62 shillings.

The fineness of gold is estimated by carat grains equivalent to 2½ dwts. troy; gold, of the highest degree of fineness, or pure, being said to be 24 carats fine. The purity of our present gold coins is 11 parts fine gold, and 1 part alloy. The sovereign, or 20 shilling piece, contains 113.001 grains fine gold, and 123.274 grains standard gold. The pound troy of standard gold is coined into 46 sovereigns and $\frac{89}{120}$ths of a sovereign, or into 46*l.* 14*s.* 6*d.* The mint or standard price of gold, is, therefore, said to be 46*l.* 14*s.* 6*d.* per lb. troy, or 3*l.* 17*s.* 10½*d.* an ounce.

Why has not the standard been preserved inviolate?

Because of the necessities of governments, and the unfounded notion, so generally diffused, that coins derived their value rather from the coinage than from the quantity of metal contained in them. Coins have been less enfeebled in England than in any other country; but even here the quantity of silver in a pound sterling, is less than the *third* part of a pound weight, the quantity it contained in 1300.

Why is money called sterling?

Because in the time of Richard I., money coined in the east part of Germany, came in special request in England, on account of its purity, and was called Easterling Money, as all the inhabitants of those parts were called Easterlings; and soon after some of these people, skilled in coining, were sent for to London, to bring the coin to perfection, which was soon called *Sterling*, from Easterling.

Money, as a medium of commerce, is first mentioned in Genesis, chap. xxiii., when Abraham purchased a field as a sepulchre for Sarah, in the year of the world, 2139: money was first made at Argos, 894 years B.C.; has increased eighteen times in value from 1290 to 1530; and twelve times in value from 1530 to 1789. Silver has increased thirty times its value since the Norman Conquest: viz. a pound in that age was three times the quantity it is at present, and ten times its value in purchasing any commodity.

Why is money also called coin and cash?

Because coin (*cuna pecunia*,) from the French *coign*, i. e. *angulus*, a corner, whence it is supposed that the most ancient coin was square. *Cash* is from the French term *caisse*, i.e. chest or coffin, for the keeping of money.

The coining-press was introduced into England in 1562; and machinery for coining by Boulton and Watt, at Soho, near Birmingham, about the year 1800. The coining-press of the Royal Mint has already been noticed.*

Why is there alloy in coins?

Because it may save the trouble and expense that would be incurred in refining the metals to their highest degree of purity; and because, when its quantity is small, it renders the coins harder, and less liable to be worn or rubbed.

Why is there a cross and pile side of a coin?

Because Constantine, with religious zeal, put a cross in place of the beast (to be explained); and in the old Gaulish language, a ship was called *pile:* hence also the game of cross and pile, and the word *pilot*.

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* See MECHANICS, p. 27

Why is not the value of money the same in all countries?

Because the use of coined money does not change the principle on which exchanges were conducted previously to its introduction. The coinage saves the trouble of weighing and assaying gold and silver, but it does nothing more. It declares the weight and purity of metal in a coin; but the *value* of that metal or coin is, in all cases, determined by those principles which determine the value of other things, and would be as little affected by being recoined with a new denomination, as the burden of a ship by a change of name. Money is, indeed, as much a commodity, as bars of iron or copper, sacks of wheat, &c.

Why do we use the term a pound?

Because, originally, the coins of all countries seem to have had the same denomination as the weights commonly used in them, and contained the exact quantity of the precious metals indicated by their names. Thus, the *talent* was a weight used in the earliest period, by the Greeks; the *as*, or *pondo*, by the Romans; the *pound* by the English and Scotch; and the *livre*, by the French: and the coins originally in use in Greece, Italy, and France, bore the same names, and weighed precisely a talent, a pondo, a livre, and a pound.

The metal which our ancestors used as their medium of exchange, they first divided by pounds, which word still remains among us to signify twenty shillings; this being about the just value that so much copper bore in those days. This was called *as* in Latin, which, according to Varro, is derived from *æs*, signifying copper. They used it first in bullion, unmarked—but to save the trouble of weighing this pound, or the lesser parts of it, and to give it a readier currency, they stamped upon one side the figure of a ship, as an emblem of commerce, with the weight and value; and on the reverse, the picture of one of those beasts which are designed by the word *Pecus*, as being the most prized commodities; whence money came to be afterwards called *Pecunia*, in Latin,—and hence the English word pecuniary.

Why is the guinea so called?

Because the gold with which it was first coined in the reign of Charles II. was brought from Guinea. For this reason also, the guinea originally bore the impression of an elephant.

The term *sovereign* is not new in our coinage: in the time of Edward VI. there were both sovereigns, and half-sovereigns, and nobles, as appropriate attendants on the sovereign.

Why is the shilling so called?

Because of its corruption from the word *scylling*, the etymology of which would lead us to suppose it to have been a certain quantity of uncoined silver; for, whether we derive it from *sceylan*, to divide, or *sceale*, a scale, the idea presented to us by either word is the same—that is, so much silver cut off, as in China, and weighing so much.—*Turner's Anglo-Saxons.*

Why were groats first coined?

Because, in the Saxon time, we had no silver money bigger than a penny, nor after the Conquest, till Edward III., who, about the year 1351, coined *grosses*, (groats, or great pieces,) which passed for fourpence; so the matter stood till the reign of Henry VII., who, in 1504, first coined shillings.

Why is the penny so called?

Because of its derivation from the Latin *pecunia*, money. Until the time of Edward I. the penny was struck with a cross, so deeply indented in it, that it might easily be broken, and parted on occasion, into two parts, thence called *half-pennies*; or into four, thence called *four-things*, or *farthings*. But that prince coined it without indenture, in lieu of which he first struck round halfpence and farthings.

Why was the banking system first introduced into England?

Because, in the turbulent times of the Commonwealth, the merchants and tradesmen, who had before trusted their cash to their servants and apprentices, found that no longer safe; neither durst they leave it in the Mint, by reason of the distress of majesty itself, although this was before a public deposit. In the year 1645, they first placed their cash in the hands of goldsmiths, who began to exercise both professions. We quote these facts from Pennant, who states the first regular banker to have been Mr. Francis Child, goldsmith, who began business soon after the restoration; but Granger mentions Mr. Child as successor to the shop of Alderman Backwel, a banker, in the time of Charles II., who was ruined by the shutting up of the Exchequer, in 1672: he lived in Fleet-street, near Temple Bar, where the banking business of the Childs is conducted to this day.

About fifty years after the above, in 1720, the credit of Bankers was much injured by what has been in our times called a panic, or run. Swift turned their tribulation to humorous account. Thus, in some lines of the above date:—

> "The multitude's capricious pranks
>   Are said to represent the seas;
> Which breaking Bankers and the Banks,
>   Remove their own where'er they please.
>
> * * * * * *
>
> No money left for squand'ring heirs!
>   Bills turn the lenders into debtors:
> The wish of Nero now is theirs,
>   That they had never known their letters."

Rymer mentions the draft and cheque. The money changers of Scripture, the Trapizæta of the Greeks, and the Argentarii, or Nummularii of the Romans, all illustrate the high antiquity of banking.

Why is the Bank of England an important adjunct of the Government of Great Britain?

Because it receives the taxes, pays the taxes, pays the interest of the public debt, and conducts the various other pecuniary transactions of the exchequer. For these services the bank receives a per centage, or commission, which amounts annually to about 260,000*l.* to which must be added the profit derived from the use of a floating balance due to the public, never less in amount than four millions sterling. This balance, employed in discounting mercantile bills at the rate of four per cent. yields a revenue of 160,000*l.* per annum, which being added to the commission of 260,000*l.* gives a total of 420,000*l.* as the profit which the proprietors of bank stock derive every year from the connexion subsisting between that establishment and the Treasury.—*Quarterly Review, No.* 86.

The Bank of England was first established in 1694: its projector was one Paterson, born in Dumfrieshire, and said to have died of grief, occasioned by the ingratitude with which he was treated by the world.

Why were the labours of the alchemists beneficial to mankind?

Because, however great their follies, their researches were instrumental in promoting the progress of chemical discovery. Hence, in particular, *metallic pharmacy* derived its origin. Mr. Herschel justly observes, "among the alchemists were men of superior minds, who reasoned while they worked, and who, not content to grope always in the dark, and blunder on their object, sought carefully in the observed nature of their agents for guides in their pursuits."

Why is mercury used in amalgams?

Because, being habitually fluid, it readily combines with most of the metals. When these metallic mixtures contain a sufficient quantity of mercury to render them soft at a mean temperature, they are called *amalgams.*

A work on metallurgy, and the use of quicksilver in refining gold and silver, was written by Alonzo Barba, a clergyman of the church of St. Bernard, at Potosi, in the year 1640, who has by some writers been supposed to be the inventor of amalgamation. He discovered the process by mere accident; for, being desirous of fixing quicksilver, he mixed it with fine powdered silver ore, and soon found that the mercury had attracted every particle of silver to itself, which presented him with the idea of refining metals by means of quicksilver. This experiment he made in the year 1609, but he was probably unacquainted at that time with smelting works in America, and does not appear desirous of claiming the invention of amalgamation as practised in that country. The book, though published at that late period of the art, and notwithstanding there were many superior treatises on the same subject already published in German, was considered of such importance by the Spaniards, as containing all their metallurgic secrets, that they endeavoured to suppress it: but a portion of it was translated into English in 1674.

WORKING METALS.

Why are the ancient Britons concluded to have been expert in working metals?

Because the art of working in iron and steel had risen to such perfection in the tenth century, that even the horses of some of the chief knights and barons were covered with steel and iron armour. Artificers who wrought in iron were so highly regarded in that warlike time, that every military officer had his smith, who constantly attended his person to keep his arms and armour in order. The chief smith was an officer of considerable dignity in the court of the Anglo-Saxon and Welsh kings, where he enjoyed many privileges, and his wages were much higher than those of any other artificer. In the Welsh court, the king's smith was next in rank to the domestic chaplain, and was entitled to a draught of every kind of liquor that was brought into the hall.

Why were bellows first invented?

Because they might imitate the action of the lungs and a hollow reed placed in the mouth of the blower, the latter being the first instrument employed for blowing a fire. Our common bellows appear to have been known to the ancient Greeks, and Roman lamps have been found in the form of bellows.

Why is it to be regretted that we know but little of the ancient construction of bellows?

Because more information on this subject would enlarge the knowledge we possess of the metallurgy of the ancients.

Strabo tells us, on the authority of an old historian, that Anacharsis the Scythian philosopher, invented the bellows, the anchor, and the potter's wheel; but this seems doubtful, as Pliny, Seneca, Diogenes, Laertius, and Suidas, only attribute the two last to him; and Strabo also remarks, that the potter's wheel is mentioned by Homer, who lived prior to the time of Anacharsis. It is, therefore, probable that the latter became acquainted with the invention on his travels, and having made it known to his countrymen, was looked upon as the inventor.—*Beckmann.*

Why are forge-bellows constructed with three boards?

Because they are required to keep up a constant and unremitting stream of air through the fuel, to keep it in vivid combustion. Thus, the centre board is fixed, and furnished with a valve opening upwards, the lower board being movable with a valve also opening upwards, and the upper board being under a continual pressure by weights acting upon it. When the lower board is let down, so that the chamber between it and the middle board is enlarged, the air included between these boards being rarefied, the external pressure in the atmosphere will open the valve in the lower board, and the chamber between the lower and the middle boards will be filled with air in its common state. The lower board is now raised by the power which works the bellows, and the air between it and the middle board is condensed. It cannot escape through the lower valve, because it opens upwards. It acts therefore, with a pressure proportional to the working power on the valve in the middle board, and it forces open this valve, which opens upwards. The air is thus driven from between the lower and middle boards into the chamber between the middle and upper boards. It cannot return from this chamber, because the valve in the middle board opens upwards. The upper board being loaded with weights, it will be condensed while included in this chamber, and will issue from the nozzle with a force proportionate to the weights. While the air is thus rushing from the nozzle, the lower board is let down and again drawn up, and a fresh supply of air is brought into the chamber between the upper and middle board. This air is introduced between the middle and upper board before the former supply has been exhausted, and by working the bellows, with sufficient speed, a large quantity of air will be collected in the upper chamber, so that the weights on the upper board will force a continual stream of air through the nozzle.—*Lardner.*

There are usually two blast-holes to conduct the stream of air from the bellows to the laboratory of the furnace, placed on opposite sides, but so angled that the streams do not impinge on each other. The bellows are commonly cylindrical, and their pistons are worked by a steam-engine.

Why are these bellows superior to the house-bellows?

Because the latter are constructed only with two boards, and have thus only an intermitting action, or blow by fits, the action being suspended while the upper board is being raised.

Why are German bellows made of wood superior to
e in common use?

Because the effect produced by them is stronger and more uniform, and they last longer. Some idea may be formed of this contrivance from the following sketch. The entire machine is composed of two boxes placed over each other, the uppermost of which can be moved up and down, in the manner of a lid with a hinge; but the sides of the upper box are sufficiently large to contain the lower between them, when raised to its greatest extent. Both are fastened together at the smallest extremity, where the pipe is inserted by a strong iron bolt. Thus, when the boxes fit each other with exactness, and the upper is raised over the under, which is immovable, the space contained within both will be increased: consequently, more air will rush in through the valve in the bottom of the lower one; and when the upper box is again pressed down, this air will be expelled forcibly through the pipe. The only difficulty is to prevent any portion of the air from escaping at any other part of the machine than the orifice of the pipe; and this is obviated by the simple contrivance of placing movable slips of wood at the inner sides of the uppermost box, which, by means of metal springs are pressed to the sides of the lower box, and fill up the intervening space. —*Beckmann.*

IRON.

Why is the use of iron believed to have been known in the earliest ages?

Because of its frequent mention in the bible: thus, Tubal Cain, who lived nearly 4,000 years before the commencement of the Christian era, was "an instructer of every artificer in brass and iron." (Gen. iv. 22.) and we read that Abraham took a knife to slay his son Isaac. (Gen. xxii. 10.) In these early times too, mention is made of shears and of shearing of sheep. (Gen. xxxviii. 12, 13.)

Why is this knowledge supposed to have been afterwards lost?

Because many of the ancient nations used stones, flints, the horns and bones of various animals, the bones and shells of fish, reeds and thorns, for every purpose in which the moderns now use edge tools of iron and steel.

Chronology informs us, iron was first discovered by the burning of Mount Ida, 1406 B.C. In England by the Romans, soon after the landing of Cæsar: first discovered in America, in Virginia, 1715: first cast in England, at Blackstead, Sussex, 1544.

Why was iron, at one period forbidden to be used by the Romans, except in agriculture?

Because they thought iron poisonous, and that wounds made with iron instruments healed with difficulty. Chemistry has, however, exposed this fallacy. Fourcroy says iron is the only metal which is not noxious, and whose effects are not to be feared. Indeed, its effects on the animal economy are evidently beneficial.

Why is iron the most useful of metals?

Because it becomes softer by heat, and has the capability of being welded to another piece of iron, so as to form one entire mass: and this may be done without rivets, solder, or melting either of the pieces. No other metal possesses this singular property, except platinum.

An iron wire only one-tenth of an inch in diameter, will carry 450 pounds without breaking. A wire of tempered steel of the same size will carry nearly 900 pounds.—*Black.*

Why has the iron trade of Great Britain increased so extraordinarily since the year 1750?

Because then pit-coal began to be generally used for extracting cast iron from its ores. In 1740, England and Scotland did not possess more than 59 furnaces, producing 17,000 tons; whereas in 1827, they had increased to 284 furnaces, producing 690,000 tons. A writer in a French Journal, therefore, describes pit-coal as "the prime element of the manufactures and the wealth of England." The mean annual amount of the exportation of iron and steel from this country, in bars and wrought works, is from 1,200,000*l.* to 1,500,000*l.* The annual quantity of iron manufactured in Great Britain is 690,000 tons.

In the great iron works, the ore, broken into small pieces, and mixed with lime or some other substance to promote its fusion, is thrown into the furnace; and baskets of charcoal or coke, in due proportion, are thrown in along with it. A part of the bottom of the furnace is filled with fuel only. This being kindled, the blast of the great bellows is directed on it, and soon raises the whole to a most intense heat: this melts the ore immediately above it, and the reduced metal drops down through the fuel and collects at the bottom. The rest sinks down to fill up the void left by the consumed fuel, and this, in its turn, comes next in the way of the bellows, and is also reduced. More ore and fuel are supplied above, and the operation goes on till the melted metal at the bottom, increasing in quantity, rises almost to the aperture of the blast; it is let out by piercing a hole in the side of the furnace, and then forms what are called *pigs* of cast iron.—*Parkes.*

The Butterley iron-works are amongst the most important in this country. Here are three furnaces, each capable of producing thirty-five tons of pig iron, or crude cast iron, per week. The blast furnaces are about forty feet high, and about thirteen in the largest diameter. When charged, they contain about 3,500 cubic feet of iron stone, coke, and lime-stone, which produce one ton of melting iron. When heated, they are kept in a state of intense heat for many months or years, without intermission, and are constantly supplied at the tops with materials. Blast cylinders, worked by a steam-engine of 80-horse power, continually urge a stream of air into the furnace. The volume of air thus supporting the combustion, may be estimated by the contents of these cylinders, which are six feet diameter, with a stroke of eight feet long, repeated thirteen times per minute, and doubled by a reciprocity motion, causing a consumption or decomposition of 6240 cubic feet of air per minute. In the foundery attached to these works, were cast the iron-work of Vauxhall Bridge; the columns of the King's Theatre in the Haymarket; many of the works in the dock-yard at Sheerness; the famous roof of the Rum Quay at the West India docks; and nearly all the pipes of the West Middlesex water-works. Sugar-mills for expressing the juice from the cane in the Colonies, are also manufactured here; and the proprietors have exported upwards of 150 steam-engines to the same quarter within the last seven years. Here was made the steam-engine which supplies Calcutta with water: the nabob or king of Oude, has had one to work a pleasure steam-yacht, and another on a small scale to work *punkas* or large fans, to ventilate and cool his apartments.

At the Cognor Park works, on the borders of Derby and Notts. the Butterley Company manufacture bar iron in all its forms of convenience and utility. Their vastness is thus described: " Conceive a space as large as Lincoln's Inn Fields, covered with extended fires and smoke, with the rumbling of blasting engines, the thumping of welding-hammers, and scores of men carrying about masses of iron at a white heat: imagine furnaces of melted iron, with their narrow doors, through which light flows with sensible momentum, and blinds those who dare to look upon the liquid lakes within. behold sets of revolving wheels, one of them twenty four feet in diameter, weighing twenty tons, yet whirling seventy-two times in a minute; and see the connexion of this balance and regulator: view twenty kinds of apparatus, alive, as it were, and with Cyclops moving among them, and you have before you these vast Derbyshire iron-works. To comprehend, in a sentence, the works carrying on by the Butterley Company only, I may observe, that in its iron and coal-works it employs twenty-five steam-engines with the power of 700 horses, and at this time gives employment to 1500 men, as miners, colliers, furnace-men, moulders, steam-engine fitters, smiths, labourers, &c."*

Why is Swedish superior to British iron?

Because the Swedes smelt with wood instead of coke. It is imported into England in great quantities, and is chiefly used for carbonization in steel.

Why is iron deprived of its malleability by long-continued hammering?

Because it loses a portion of its latent caloric; Dr. Black being of opinion that metals are malleable in proportion to the matter of heat which they contain in a latent state.

Why is cast-iron puddled and rolled?

Because a principal part of the foreign substances are thus burned away or squeezed out, and malleability is conferred upon the metal by rendering it more pure.

By this curious process of *puddling*, cast-iron, after it has been to a certain extent *refined*, by refusion in a forge, is, in this country, converted into wrought iron. The cast iron is put into a reverberatory furnace, and when in fusion, is stirred, so that every part may be exposed to the air and flames. After a time, the mass heaves, emits a blue flame, gradually grows tough, and becomes less fusible, and at length pulverulent; the fire is then urged, so that the particles again agglutinate at a welding heat, and are gradually wrought up into masses. In that state of intense heat, the masses are passed successively between rollers, and the bars made malleable. They are cut into pieces, placed in parcels in a very hot reverberatory, and again hammered or rolled out into bars. They are thus rendered more tough, flexible, and malleable, but much less fusible, and may be considered as nearly pure iron.

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* Abridged from Sir R. Phillips's *Personal Tour*, Part ii. 1830.

Why is iron better cast perpendicularly than horizontally?

Because of the pressure of the upright column, which renders the iron much less liable to air-bubbles and imperfections of that kind, which defeat the skill and calculations of the machinist. If this upright pressure be increased by a weight of extraneous metal, the casting is still more likely to be sound.

Why does a rod of wrought iron, if plunged into cast iron in fusion, become steel?

Because the iron absorbs part of the carbon. What is called *case-hardening*, is a conversion of the *surface* of iron into steel.

Why is the process by which iron is converted into steel, called cementation?

Because it consists in heating bars of the purest iron in contact with charcoal; it absorbs carbon, and increases in weight, at the same time acquiring a blistered surface. This, when drawn down into smaller bars, and beaten, forms *tilted steel;* and this broken up, heated, welded, and again drawn out into bars, forms *shear-steel.*

In this process it has been commonly considered that the carbon combines *mechanically* with the iron; our chemists have, however, long been of opinion, that it is a *chemical* combination that takes place, by the gradual absorption of carbon in the gaseous state, by the iron. This fact has been proved by Mr. Charles Mackintosh, of Crossbasket, Lanark, who has taken out a patent for preparing steel, by subjecting the iron to a stream of carburetted hydrogen gas, evolved from coal under distillation. This iron is enclosed in a pot or crucible in the furnace, and when arrived at the proper heat, a stream of gas is directed by a pipe into the crucible, which has another aperture to allow that part of the gas to escape, which has not been taken up by the metal. Steel, in ingots, is porous; but, to confer solidity, it is hammered, tilted, and rolled. At Attercliffe, near Sheffield, are extensive works for these purposes. Here, by the power of a water-wheel, fifteen feet in diameter, hammers are worked, weighing from 3 to 4½ cwt. and strike, at ten or twelve inches fall, from 100 to 220 times in a minute. The ingots, at a strong red heat, are exposed to the action of these hammers, and the metals condensed into bars, which are next submitted, at the same degree of heat, to the tilting hammer, which gives 300 strokes per minute: lastly, they are rolled or flattened into sheets, and drawn into lengths. Six tons a week are hammered down by one hammer; about three tons are tilted; and twenty-four tons can be rolled, working night and day, by relays of hands.

The making of steel is a British manufacture scarcely sixty years old. Previously it came from Austria and Syria, and was dear and little used. It is, however, now heated, welded, cut, and moulded in this country, with nearly the same facility as deal wood by an ordinary carpenter.

Why does a drop of nitric acid, let fall upon steel, occasion a black spot?

Because the iron is dissolved, and the carbon thereby exposed to view.—*Parkes.*

Why is steel tempered?

Because, when steel is heated to a cherry-red colour, and then plunged into cold water, it becomes so extremely hard and brittle, as to be unfit for almost any practical purpose; and *tempering* reduces it from this extreme hardness, by heating it to a certain point or temperature.

The polishing of steel is not executed in the same manner as that of the softer metals: the steel is not polished until it has been hardened, and the harder it is, the more brilliant will be its polish. Rotten-stone, a kind of very light tripoli, but finer than the other sorts, and found near Bakewell, in Derbyshire, is esteemed for general polishing; but steel, from its extreme hardness, requires to be polished with emery.

Why are various colours produced on heated steel?

Because of the oxidation which takes place, as is proved from the circumstance that when steel is heated and suffered to cool under mercury or oil, none of the colours appear; nor do they when it is heated in hydrogen or nitrogen.—*Brande.*

Why is it customary to judge of the temper of steel by its colours?

Because, the surface being a little brightened, exhibits, when heated, various colours, which constantly change as the temperature increases. Thus, when steel is placed in a bath heated to 600°, the first change is at about 430°, which is very faint; at 460°, the colour is straw, becoming deeper as the temperature is increased; at 500°, the colour is brown; this is followed by a red tinge, with streaks of purple, then purple; and at nearly 600°, it is blue. The degrees at which the different colours are produced, being thus known, the workman has only to heat the bath with its contents up to the required point. For example, suppose the blade of a pen-knife, (or a hundred of them,) to require tempering; they are suffered to remain in the bath until the mercury in the thermometer rises to 460°, and no longer, that being the heat at which the knife (supposing it to be made of the best English cast steel) will be sufficiently tempered.

Why is cast steel so called?

Because it is prepared by fusing blistered steel with a flux composed of carbonaceous and vitrifiable ingredients, casting it into ingots, and afterwards by gentle heating, and careful hammering, giving it the form of bars.

Why is the Peruvian steel so called?

Because it is an alloy of steel with certain portions of other metals from Peru. It is, technically speaking, *sadder*, not so easy to work as other steel, and yet much harder and tougher than any other.

CUTLERY.

Why is steel used for making cutting instruments?

Because it combines the fusibility of cast with the malleability of bar iron, and when heated and suddenly cooled, becomes very hard.

The rapidity with which razors, knives, &c. are produced from the raw material, is truly astonishing. Thus in the workshops at Sheffield, we may in a few minutes see dinner knives made from the steel bar and all the process of hammering it into form, welding the tang of the handle to the steel of the blade, hardening the metal by cooling it in water and tempering it by de-carbonizing it in the fire.

The number of hands through which a common table-knife passes in its formation is worthy of being known to all who use them. The bar steel is heated in the forge by *the maker*, and he and *the striker* reduce it in a few minutes into the shape of a knife. He then heats a bar of iron and welds it to the steel so as to form the tang of the blade which goes into the handle. All this is done with the simplest tools and contrivances. A few strokes of the hammer in connexion with some trifling moulds and measures, attached to the anvil, perfect, in two or three minutes the blade and its tang or shank. Two men, the maker, and striker, produce about nine blades in an hour, or seven dozen and a half per day. The rough blade thus produced, then passes through the hands of the filer, who files the blade into form by means of a pattern in hard steel. It then goes to the hafters to be hafted in ivory, horn, &c. and then to the finisher. In this profession, every table-knife, pocket-knife, or pen-knife, passes, step by step, through no less than 16 hands or 144 separate stages of workmanship.

Sheffield employed about 15,000 persons in these departments, four years since:

On table-knives	2,940
On spring-knives	2,190
On razors	478
On scissors	806
On files	1,284
On saws	400
On edged tools	541
On forks	480
In the country	130
In the plated trade nearly	2000
About	10,549

Besides those who are employed in Britannia-metal ware, smelting, optical instruments, grinding, polishing, &c. &c. making full 5,000 more. There are full 1,700 forges engaged in the various branches of the trades, and of course as many fires.

Why are the most minute instruments generally made with good steel?

Because it is much more ductile than iron: a finer wire being drawn from it than from any other metal.

Why is Wootz or Indian steel the most valuable for making edge tools?

Because it is combined with a minute portion of the earths, alumina and silica; or rather perhaps, with the bases of these earths. Whether the earths are found in the oar, or are furnished by the crucible in making the steel, is not certainly known; nor is the Indian steel-maker probably aware of their presence. Wootz, in the state in which it is imported, is not fit to make into fine cutlery. It requires a second fusion, by which the whole mass is purified and equalized, and fitted for forming the finest edge instruments.—*Brande.*

Why does a razor operate best when dipped in hot water?

Because the temperature of the blade has then been raised, and the fineness of the edge proportionally increased.

In some experiments, the knife edges attached to the pendulum described by Captain Kater, in *Phil. Trans.* 1818, on being carefully hardened and tempered in the bath at 432°, were, on trial, found too soft. They were a second time hardened, and then heated to 212°, at which point the edges were admirably tempered. This, it will be remembered, is the heat of boiling water, and further illustrates the preceding question.

In the manufacture of a razor, it proceeds through a dozen hands; but it is afterwards submitted to a process of grinding, by which the concavity is perfected, and the fine edge produced. They are made from 1*s.* per dozen, to 20*s.* per razor, in which last the handle is valued at 16*s.* 6*d.*—Scissors, in like manner, are made by hand, and every pair passes through sixteen or seventeen hands, including fifty or sixty operations, before they are ready for sale. Common scissors are cast, and when riveted, are sold as low as 4*s.* 6*d.* per gross! Small pocket knives too are cast, both in blades and handles, and sold at 6*s.* per gross, or a halfpenny each! These low articles are exported in vast quantities in casks to all parts of the world.

ZINC.

Why is Zinc useful in the arts?

Because, in combination with copper or tin, in various proportions, it forms some of the most useful compound metals or alloys. Thus, with copper, it constitutes brass, pinchback, and tombac; with little copper, Prince's metal;* with tin and copper, bronze.

Roofs covered with zinc are very numerous in the Low Countries but have one bad quality. In cases of fire, the zinc being very combustible, soon becomes inflamed, and falling all around, occasions great danger to those who approach the building. In short, zinc is the most combustible metal we have. If beaten out into thin leaves, it will take fire from the flame of a common taper.

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*See DOMESTIC SCIENCE, page 65.

Why has the oxide of zinc been substituted for white lead in house-painting.

Because it preserves a good colour much longer: it is not, however, of so perfect a white as lead.

TIN.

Why did the ancients mix tin with their copper coins and edge tools?

Because it occasioned the coins to wear longer, and it imparted sufficient hardness to the copper to render it capable of forming very good cutting instruments. Mr. Parkes, in analysing several Roman brass coins, from various periods of the Empire, found tin to be a component part in all of them.

Why is not Spanish tin used in this country?

Because it bears a prohibitory duty of 30*l.* per cent. It is raised in great quantities in South America, and is very pure, but not so neatly manufactured as the Cornish tin. According to Aristotle, the tin mines of Cornwall were known and worked in his time. Diodorus Siculus, who wrote 40 years before Christ, describes the method of working these mines, and says, that their produce was conveyed to Gaul, and thence to different parts of Italy. The miners of Cornwall were so celebrated for their knowledge of working metals, that about the middle of the 17th century, the renowned Becher, a Physician of Spire, and tutor of Stahl, came over to this country to visit them.

A celebrated tin mine was the famous *wherry mine*, near Penzance. The shaft through which the miners went down to work, was situated nearly 100 yards below water mark. "The opening of this mine" says Dr. Maton, "was an astonishingly adventurous undertaking. Imagine the descent into a mine through the sea, the miners working at the depth of 17 fathoms below the waves; the rod of a steam engine, extending from the shore to the shaft, a distance of nearly 120 fathoms, and a great number of men momentarily menaced with an inundation of the sea, which continually drains in no small quantity through the roof of the mine, and roars loud enough to be distinctly heard in it." The working of this mine was wholly given up in the year 1798.

Such is the mineral wealth of Cornwall, that it contains more men, who possess fortunes, sprung from the mines, of five and from that to twenty thousand pounds, than there are in any other county of England, excepting the metropolis and its vicinity; and there are some instances of individuals acquiring from fifty to two hundred thousand pounds, from the mines, and by a fortunate course of trade.

Why should tin be chosen for its lightness?

Because its purity is in exact ratio with its levity; while gold, on the contrary, unless alloyed with platinum, is fine in proportion to its density.

Why is tin so important to the dyer?

Because it is employed to give a brightness to cochineal,* archil, and other articles used in forming reds and scarlets; and to precipitate the colouring matter of other dyes. For these purposes it is previously dissolved in a peculiar kind of *aqua-fortis*, called *dyers' spirit.*

Tin is consumed in large quantities by the dyers; it is also used for covering sheet iron to prevent its rusting, and in forming plumbers' solder, speculum metal, pewter, and some other alloys. Its oxides are used in polishing glass, in glazing some kinds of earthenware, &c.

Why is tin-plate so called?

Because it is made by dipping clean iron plates into melted tin. When tin-plate is washed over with a weak acid, the crystalline texture of the tin becomes beautifully evident, forming an appearance which has been called *moire metallique.*

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* See Zoology—*Insects*, page 258.

Why are pins whitened by boiling in grain-tin and supertartrate of potash?

Because the tartaric acid first dissolves the tin, and then gradually deposits it on the surface of the pins, in consequence of its greater affinity for the zinc, of which the brass wire is composed.

Why were the Stannary Courts so called?

Because they regulated the affairs of the tin (*Stannum,* Latin,) mines, and determined causes among the tinners, whether criminal or actions for debt. At Lydford, on the borders of Dartmoor, was one of the Stannary prisons: hence the Devon and Cornwall saying:

"First hang and draw,
Then hear the cause by Lydford Law;"

or Lydford Law, by which they hang men first, and try them afterwards.

LEAD.

Why is lead employed in refining the precious metals?

Because when mixed with them in a great heat, it rises to the surface combined with all heterogeneous matter. Lead is employed to cover buildings, to form water-pipes, (though Vitruvius, the Roman architect, in the time of Augustus, condemned this practice,) and to make a great variety of vessels for economical purposes. Its oxides are used for dyeing and calico-printing, in the manufacture of glass, earthenware, and porcelain: and lead is capable of forming various alloys. There is also a large consumption of lead in making shot.*

Why is lead employed in the manufacture of white metal buttons?

Because it has been discovered that a certain proportion of lead may be mixed with the metal formerly used, without injuring the appearance of the button; thus affording a very considerable additional profit to the manufacturer.

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* See MECHANICS, p. 20.

Why is lead employed to correct harsh wine?

Because it has the property of imparting a saccharine taste when dissolved in acids, as in that of the wine. The ancients knew that this metal rendered harsh wine milder, but it was not universally known to be poisonous. According to Pliny, the Greeks and Romans proved the quality of their wines by dipping a plate of lead in them. Lead will also take off the rancidity of oils.

Why were blocks of lead called pigs?

Because they might be distinguished from larger blocks, called *sows*, which latter term is still retained in the word *sow-metal*. In 1773, a pig of lead was dug up near Tamworth, with an inscription of the date 76, A.D., or 1697 years old; thus proving lead to have been used by the Romans in this country.

Why is lead cast in such regular sheets?

Because the melted metal is suffered to run out of a box through a long horizontal slit upon a table prepared for the purpose, while the box is drawn by appropriate ropes and pulleys along the table, leaving the melted lead behind it in the desired form, to congeal. The lead thus cast is then passed between two iron rollers placed at such a distance from each other, as will reduce it to the requisite thickness.

Why is common lead changed into red lead by melting it in ovens with a free access of atmospheric air?

Because the lead absorbs so much oxygen as to become converted into an oxide. Thus, the melted lead is exposed until the surface is covered with a pellicle; this pellicle being removed, another is formed; and thus, by successively removing the pellicle as it forms, the greater part of the lead is soon changed into a yellowish-green powder. This powder is then ground in a mill, and when it has been washed and properly dried, is thrown back into the furnace; and this, by constant stirring for thirty or forty hours, so as to expose every part to the action of the air, becomes red lead, and is taken out for use. Twenty cwt. of lead generally give 22 cwt. of red lead; so that 2 cwt. of oxygen are absorbed from the atmosphere during the process.

The only important alloys of lead are those with tin. Common *pewter* consists of about 80 parts of tin and 20 of lead. Equal parts of lead and tin constitute *plumbers' solder*; and what is termed *pot-metal*, is an alloy of lead and copper.

The reduction of native lead upon a large scale, is a sufficiently simple process. The picked ore, after having been broken and washed, is roasted in a reverberatory fire, the temperature being such as to soften but not fuse it. During this operation, it is raked till the fumes of sulphur are dissipated, when it is brought into perfect fusion; the lead, reduced by the fuel, sinks to the bottom, and runs out into oblong moulds called *pigs*; the scoriæ are again melted, and furnish a portion of less pure metal. The mines of Great Britain afford an annual produce of about 48,000 tons of smelted lead. There is a peculiar variety of native lead, called in Derbyshire *Slickensides*, which, when touched by the miners' pick, often splits asunder with a kind of explosion.*

Plumbago, graphite, or *black-lead*, is generally regarded as a true carburet of iron: it is not uncommon, though rarely found sufficiently pure for pencils; the coarser kinds, and the dust, are melted with sulphur, for common carpenters' pencils: it is sometimes used in manufacturing crucibles, and in compositions for covering cast-iron, and for diminishing friction in machinery.*

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* The practice and laws of mining in Derbyshire, are somewhat curious. Sir Richard Phillips, in his recent *Personal Tour*, tells us, "there is a large district called *the King's Field*, and as the king is entitled to a share, so any person finding a vein of ore, may, on giving notice to the *Bar-master*, an officer so called, work the said vein for his own benefit, and the king's. The Bar-master then places a cross-stick on the spot, and the vein is deemed the legal property of the discoverer, who is, moreover, entitled to a right of way to the nearest ic road."

Mr. Bakewell was informed at the celebrated mine in Borrowdale, that black-lead, to the amount of one thousand pounds, had been obtained there in one day.

Why is common white-lead made by exposing sheet-lead to acetic acid?

Because the fumes of the acid oxidize the metal Thus, a number of crucibles, holding from three to six quarts each, and nearly filled with vinegar, are placed in hot-beds of tan: upon these crucibles thin sheets of lead, rolled up in coils, are placed, one coil over each crucible. The heat of the bed occasions the vinegar to rise in vapours, and this attaches itself to the lead, and oxidizes its surface to a considerable depth. The oxide which has been thus formed, is scraped off, and the coils of lead replaced: in this manner the operation is repeated, until the whole of the metal is oxidized. This oxide, which contains a portion of carbonic acid, is afterwards washed, and ground for sale.

Why does linseed-oil, boiled with red-lead, become drying oil?

Because the oxygen of the metal combines with the oil, imparting to it the property of drying quickly.

ANTIMONY.

Why is antimony important in the arts?

Because, alloyed with lead, in the proportion of 1 to 16, and a small addition of copper, it forms the alloy used for printers' types: with lead only, a white and rather brittle compound is formed, used for the plates upon which music is engraved. With tin, antimony constitutes a kind of pewter, a term, however, applied to an alloy of lead and tin. The finest pewter consists of about twelve parts of tin and one of antimony, with a small addition of copper. A good white metal, (Britannia) used for tea-pots, is composed of 100 tin, 8 antimony, 2 bismuth, and 2 copper.

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* See MECHANICS, page 36.

COPPER.

Why is copper chosen for making trumpets and other musical instruments?

Because of its sonorous property.

Why is copper-wire chosen by wire-dancers?

Because of its great elasticity. Thus a wire 1-10th of an inch in diameter, will support nearly 300 lb.

The first copper smelting works were established at Swansea, about a century ago,—but the business has so increased, that it is calculated not fewer than 10,000 persons are now employed in the works and the collieries, and the shipping connected with them.

The following is an outline of the process by which ores of copper are reduced, as carried on upon a large scale near Swansea, where the chief part of the Cornish ores are brought to the state of metal. The ore, having been picked and broken, is heated in a reverberatory furnace, by which arsenic and sulphur are driven off. It is then transferred to a smaller reverberatory, where it is fused, and the slag which separates, being occasionally removed, is cast into oblong masses, used as a substitute for bricks. The impure metal collected at the bottom of the furnace, is granulated by letting it run into water; it is afterwards melted and granulated two or three times successively, in order further to separate impurities, which are chiefly sulphur, iron, and arsenic, and ultimately cast into oblong pieces called pigs, which are broken up, roasted, and lastly melted with charcoal in the refining furnace. Malleability is here conferred upon the copper, and its texture improved by stirring the metal with a pole of green wood, generally birch, which causes great ebullition and agitation; assays are occasionally taken out, and the metal, originally crystalline and granular when cold, now becomes fine and close, so as to assume a silky polish when the assays are half cut through and broken. The metal is now cast into cakes about twelve inches wide, by eighteen in length. Copper for brass-making is granulated by pouring the metal through a perforated ladle into water; when this is warm, the copper assumes a rounded form, and is called *belan shot;* but if a constant supply of cold water is kept up it becomes ragged, and is called *feathered shot.* Another form into which copper is cast, chiefly for exports to the East Indies, is in pieces of the length of six inches, and weighing about eight ounces each. the copper is dropped from the moulds, immediately on its becoming solid, into a cistern of cold water; and thus, by a slight oxidation of the metal, the sticks acquire a rich red colour on the surface. This is called *Japan Copper.—Brande.*

Sulphate of copper, or Roman vitriol, is much used by dyers, and in many of the arts. Fowling-pieces and tea-urns are browned, by washing them with a solution of this salt. Verdigris is an acetate of copper. Blue verditer, much used in staining paper for hanging rooms, is a nitrate of copper, combined with hydrate of lime. Mineral and Brunswick green, are likewise combinations of copper with potash, &c. At Montpellier, the manufacture of rough verdigris is part of the household business in the wine-farms, and is generally done by the women.

The annual value and produce of the copper and tin from the mines of Cornwall and Devonshire, on an average of several years, may be stated at 75,000 tons of copper ore, value £800,000. sterling; 3,250 tons of metallic tin, value £227,000.—*Bakewell's Geology.*

According to the tables of the produce of the soft metals raised in Great Britain, as given in a work entitled *Records of Mining*, the quantity raised in a year is as follows:—copper, 16,635 tons; lead, 47,000 tons; and tin, 5,816 tons.

Why is the rust advantageous to copper?

Because the corroded part is very thin, and preserves the metal beneath from further corrosion.

Why have small bells a shrill tone?

Because zinc is added to their composition, usually consisting of three parts copper and one of tin.

Why has apparatus been invented for sounding bells without pulling?

Because buildings suffer much from the sounding of bells, especially when they are very heavy. Let one, in fact, only imagine a mass of several tons swinging to and fro, and he will readily perceive how much a building must be shaken by it. In Denmark, Professor Oersted has introduced into a bell a balance; similar to that of a pendulum. An axis, by turning, raises a hammer, which, at each turn, strikes the bell, and produces a sound which cannot be distinguished from that emitted by the bell when tolled.

The largest bells in the world are to be found in Russia. The "Great Bell" of Moscow, cast in the year 1736, weighs 432,000 pounds, is 19 feet high, 21 yards in circumference at the bottom, and at its greatest thickness 23 inches.*

Why should children be cautioned against eating the imitative gold on gingerbread, &c.?

Because it is nothing more than a fine kind of brass, which is supposed to be made by cementation of copper plates with calamine, and hammered out into leaves in Germany. It is sold very cheap in this country, under the name of Dutch gold or Dutch metal. It is about five times as thick as gold leaf; that is to say, it is about one sixty-thousandth of an inch thick.

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* Mirrors are also cast of larger dimensions at St. Petersburgh, than elsewhere. In the Imperial manufactory here, was cast for Prince Potemkin, a mirror, measuring 194 inches by 100. One, of the same proportions, and valued at three thousands guineas, was cast for the Duke of Wellington, a few years since, but was broken to atoms in its conveyance from St. Petersburgh to England.

Why is tin preferable to other metals for lining copper vessels?

Because it combines with copper at a much lower temperature than is necessary to fuse the copper alone. When vessels are tinned, they are first scraped or scoured; after which they are rubbed with sal-ammoniac. They are then heated, and sprinkled with powdered resin, which defends the clean surface of the copper from acquiring the slight film of oxide, that would prevent the adhesion of the tin to its surface. The melted tin is then poured in and spread about. An extremely small quantity adheres to the copper, which may perhaps be supposed insufficient to prevent the noxious effects of the copper as perfectly as might be wished.

Why do watchmakers prefer Dutch brass to the English?

Because of its superior ductility, which is owing to the large proportion of copper contained in it; the Dutch being a compound of two atoms of copper and one of zinc, while the English is of equal parts of copper and zinc.—*Thomson.*

COBALT.

Why is cobalt extremely valuable to the manufacturers of porcelain?

Because it not only produces a beautiful colour, but endures the extreme heat of their furnaces unaltered. This colour is so intense, that a single grain of the pure oxide will give a deep tint of blue to 240 grains of glass. Smalt, or powder-blue, used by laundresses, consists of oxide of cobalt, ground impalpably with flint-glass. This is also used to give a blue tinge to writing and printing papers.

Cobalt ores generally contain arsenic: they are so contaminated with it, that the workmen who are employed seldom live many years.

Why is cobalt especially valuable in the fine arts?

Because its oxide forms the most permanent blue colour that we are acquainted with. La Grange says that the old painters used this oxide mixed with oil in their paintings, which is the reason why the sky and drapery in some old pictures are of so durable a blue.

BISMUTH.

Why is bismuth important in the composition for printing-types?

Because it has the singular property of expanding as it cools; and from this expansive property are obtained the most perfect impressions of the moulds in which the letters are cast. The larger kind of types are generally made with lead and antimony, in the proportion of from 4 to 16 parts of the former to one of the latter.

SILVER.

Why is silver alloyed with copper for plate and coin?

Because the former metal is thus rendered harder and more sonorous, while its colour is scarcely impaired.

The silver mines of Mexico and Peru far exceed in value the whole of the European and Asiatic mines: for we are told by Humboldt, that three mines, in the space of three centuries, afforded 316,023,883 pounds troy of pure silver; and he remarks that this quantity would form a solid globe of silver, 91,206 English feet in diameter. (*Jameson.*) Mr. Helms is of opinion that the Andes, if properly examined, would afford silver enough to overturn our present commercial system, by making silver as common as copper.

Silver has also been obtained from some of the lead mines of Great Britain. Bishop Watson, in his *Chemical Essays*, notes, "By the silver which was produced from the lead mines in Cardiganshire, Sir Hugh Middleton is said to have cleared two thousand pounds a month, and that this enabled him to undertake the great work of bringing the new river from Ware to London."

Why does silver tarnish and blacken?

Because of the sulphureous vapours in the atmosphere: pure water has no effect upon silver; but if the water contain vegetable or animal matter, it often slightly blackens its surface in consequence of the presence of sulphur.

Why is the German "silver" improperly so named?

Because it is nothing more than the white copper long known in China, and does not contain a particle of silver; it is only an alloy of copper, metal, and nickel. Although only now coming into known use in England, it has been no stranger to the manufactories of Birmingham for at least twenty years or more.

Why is plating so called?

Because it is performed by the application of a plate of silver to the surface of copper, which is afterwards beaten or drawn out. Amalgam of silver is sometimes employed for plating; it is applied to the surface of the copper, and the mercury being evaporated by heat, the remaining silver is burnished. A mixture of chloride of silver, chalk, and pearlash is employed for silvering brass: the metal is rendered very clear, and the above mixture, moistened with water, rubbed upon its surface. In this way, thermometer scales and clock dials are usually silvered.

A note upon the duty on plate will show how large a portion of gold and silver is annually diverted from the purposes of coin to those of ornament and luxury. The rate of duty upon silver wrought plate in 1804, was 1*s.* 3*d.*; upon gold 16*s.* per ounce; it was afterwards raised to 1*s.* 6*d.* upon silver, and to 17*s.* upon gold. At this time the annual net duty was less than 5000*l.*;

in 1828, it was upwards of 105,000*l.*; a rise more than twenty-fold, notwithstanding the greatly diminished supply from the mines, and the consequent increasing value of the precious metals.

Why is coal gas injurious to silver and plated goods?

Because of the sulphuretted hydrogen which it contains.

Why is the Birmingham and Sheffield plate superior to that formerly made?

Because the old method was by dissolving mercury in nitrous acid, dipping the copper, and depending on the affinity of the metals, by which a very slight article was produced. But at Sheffield and Birmingham, all plate is now produced by rolling ingots of copper and silver together. About the eighth of an inch in thickness of silver is united by heat to an inch of copper in ingots about the size of a brick. It is then flattened by steel rollers worked by an eighty-horse power. The greater malleability of the silver occasions it to spread equally with the copper into a sheet of any required thickness, according to the nature of the article for which it is wanted. Plated metal, the eighth of an inch thick, is thus rolled by the hand into ten times the surface, the silver spreading equally; and the plating would be perfect if the rolling had reduced it to the thinness of silver paper! This mode of plating secures to modern plate a durability not possessed by any plate silvered by immersion. Hence plated goods are now sought all over the world, and, if fairly used, are nearly as durable as silver itself. Of this material, dinner and dessert services have been manufactured at from fifty to three hundred guineas, and breakfast sets from ten to two hundred guineas, as sold on the spot.

GOLD.

Why is gold alloyed with copper for coin?

Because it is thus made harder than pure gold, and resists wear better than any other alloy except that with silver.

The produce of the Ural gold mines amounted, in 1827, to 672,416*l*. Gold is also found in the Rhine; but the quantity is so scanty, that, the washer considers it a good day's work, if he succeed in collecting to the value of 5*s*. or 6*s*. From the official accounts of the yearly produce obtained from that stream in the Grand Duchy of Baden, we observe the value was, in 1821-2, £603; 1826, £808; 1827-8, £943. The last produce, small as it may appear, for it scarcely exceeded 17 pounds in weight, showed so considerable an increase upon preceding years, that a great impulse was given to this branch of industry in Baden.

We have already noticed the malleability of gold, though not its actual limit; * for the gold-beaters find it necessary to add three grains of copper in the ounce, to harden the gold, which otherwise would pass round the irregularities of the newest skins, and not over them: and in using the old skins, which are not so perfect and smooth, they even add twelve grains. The wire which is used by the lace-makers, is drawn from an ingot of silver, previously gilded. In this way, from the known diameter of the wire, or breadth when flattened, and its length, together with the quantity of gold used, it is found, by computation, that the covering of gold is only 1-12th part of the thickness of gold leaf, though it is still so perfect as to exhibit no cracks when viewed through a microscope.

Fifty thousand pounds worth of gold and silver are said to be annually employed at Birmingham in gilding and plating, and of course lost for ever as bullion. —The ductility of gold is such, that one ounce of it is sufficient to gild a silver wire more than 1,300 miles long.

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* See MECHANICS, p. 17.

Why is mercury used to separate gold and silver from the extraneous matter found with those metals?

Because, by triturating the mass with mercury, the gold and silver become amalgamated with it; and afterwards this amalgam is submitted to heat, when the mercury sublimes; the precious metals leaving in a state of purity.

The gilding of buttons is, in part, similarly effected. When the buttons, which are of copper, are made, they are dipped into dilute nitric acid, to clean them, and then burnished with a hard black stone: they are then put into a nitric solution of mercury, and stirred about with a brush till they are quite white: an amalgam of gold and mercury is then put into an earthen vessel with a small quantity of dilute nitric acid; and in this mixture the buttons are stirred till the gold attaches to their surface: they are then heated over the fire till the mercury begins to run, when they are thrown into a large cap made of coarse wool and goat's hair, and in this they are stirred about with a brush. The mercury is then volatilized, by heating over the fire in a pan. By Act of Parliament, a gross of buttons, of an inch diameter, are required to have five grains of gold on them; but many are deficient even of this small quantity.

Why is false gilding so called?

Because it is the art of applying thin leaves of silver, or of tin, to the substance to be gilded, and then rubbing them over with a yellow transparent colour, through which the metallic splendour appears: this is very old; and a method of affixing a white metal to paper, and then covering it with a gold varnish, has been known in China from the earliest ages. It appears also to have been employed at a very remote period for gilding leather, of which many specimens may be found in ancient leathern tapestry.

PLATINUM.

Why is platinum so called?

Because it resembles silver; the term, in the language of Peru, meaning "little silver."

Platinum may always be known from other metals by its superior specific gravity, it being the heaviest body in nature. The important uses to which this precious metal may be applied, can be easily conceived, when it is considered that it unites the indestructibility of gold to a degree of hardness almost equal to that of iron; that it resists the action of the most violent fire, and also of the most concentrated acids. One of its more useful applications has been to the coating of copper with as much ease as the common operation of tinning. The high value of platinum is however very much against its general adoption, for although much cheaper than gold, it is worth between four and five times its weight of silver.

Why is the alloy of steel and platinum well adapted for mirrors?

Because it takes a fine polish and does not tarnish.

Why is platinum well adapted for the manufacture of rings and chains?

Because it has the property of being united by welding, either one piece to another, or with iron, or steel. Hence its durability must add to its value.

A beautiful coinage of platinum has lately been issued in Russia, the metal being found in considerable quantities in the Uralian mountains of Siberia.

Why is rhodium used for the nibs of metallic pens?

Because of its extreme hardness and durability. For this successful application, the elegant arts are indebted to the suggestion of the late Dr. Wollaston.

GLASS.

Why is lead important in glass?

Because its oxide, in the form of litharge, or minium, increases the fusibility of the compound, gives it greater tenaciousness when hot, increases its refractive power, and enables it to bear sudden changes of temperature. It is a copious ingredient in the *London flint glass*, celebrated for its brilliancy when cut, and used for most optical purposes. Lead, however, renders glass so soft as easily to scratch.

The manufacture of glass is as follows:—The glass-pots are placed round a dome-shaped furnace, built upon arches, and open beneath for the free admission of air; there are generally six in each furnace, and they are entirely enclosed, except at an orifice on the side opening into a small recess formed by the alternate projection of the masonry and the flues, in which the workmen stand. Coal is the fuel employed, and the furnace is so built that a rapid current of flame may be directed round each glass-pot, which afterwards passes out with the smoke into the dome and chimney, heating a broad covered shelf in its passage, which is the annealing oven. The materials, or fret, being fused, and the impurities removed, gradually become clearer, abundance of air-bubbles are extricated, and at length the glass appears uniform and complete; the fire round each individual pot is then damped, till its contents acquire a consistency fit for working; the whole process requiring about forty-eight hours from the time the pots are filled. At the working heat, which is a full red, the glass has a peculiarly tenacious consistency, and as it adheres but feebly to polished metals, it is easily wrought and managed with iron tools.*

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*Mr. Brande, in a note to his *Manual of Chemistry*, observes: "All common glass, when reduced to a fine powder, is more or less acted on by boiling water, which separates the alkali, and its entire disintegration seems only to be prevented by the insolubility of the silica. Glass which has long been exposed to the weather, frequently exhibits a beautiful irridescent appearance, and is so far decayed, that it may be scratched with the nail. Several years ago, I examined some bottles of wine which had lain in a wet cellar, near the Bank, upwards of 150 years, having been deposited there (as circumstances proved) previous to the great fire of London in 1666. The glass was soft, and greatly corroded upon the surface, in consequence of the abstraction f its alkali. The wine appeared to have been Malaga and Claret; the r had perished, but the former was still vinous."

It is a curious fact in the history of discovery, that the manufacture of glass is unknown at Sidon, though this part of the country was once famous for the discovery of, as well as production of articles in, that material. The story of the discovery of glass by Phœnician mariners at Belus, near Sidon, in Syria, is mentioned by Pliny. Dyeing, however, is still practised, though not with the same success as among the ancient Tyrians, who were descended from the builders of Sidon. The standard of Syria in arts and manufactures, is, indeed, every where, much below that of the most backward nation in Europe.

Why do all glass articles require to be carefully annealed, or suffered to cool very slowly?

Because they would otherwise be remarkably brittle, and apt to crack, and even fly into pieces upon the slightest touch of any hard substance.

Why are plate-glass windows superior to those of common glass?

Because the two surfaces of common window-glass are not perfect planes, and not perfectly parallel to each other, as in the case of plate-glass; whence objects seen through the former, appear generally more or less out of shape; and hence comes the elegance and beauty of plate-glass windows; and the singular distortion of things viewed through that swelling or lump of glass which remains where the glass-blower's instrument was attached, and which appears at the centre of certain very coarse panes.

The variation is also thus philosophically explained: "As it is the obliquity between the passing ray and the surface, which, in any case of refraction, determines the degree of bending, a body seen through a medium of irregular surface, appears distorted, according to the nature of that surface."—*Arnott.*

Why is plate-glass so expensive?

Because of the difficulty of producing a perfect plate, without specks, bubbles, or waves, and the risk of breakage. Its manufacture is as follows:

The materials being fused, are poured upon a hot copper-plate; the mass is then rolled out, annealed, and afterwards polished by grinding with sand, emery, and colcothar.

Previously to 1559 all the glass employed in mirrors was *blown;* when a Frenchman, named Thevart, discovered the art of *casting* it. The art of polishing it was invented by Rivière Dufresny. The French glass for the royal manufactories is now cast at Tourlaville, near Cherbourg, and at St. Gobin an ancient *chateau* near la Fere; it is afterwards sent to Paris to be polished, silvered, and cut. Glasses are finished here to the value of nearly 600*l.* each, and are sometimes 10 feet in height by 6½ in width.

The price of large-sized pier-glasses is within the reach of the most moderate incomes, and there is scarcely a family in France which does not possess one or two; while, as we all know, they are rarely to be met with in England, except in expensively furnished houses.

Why was the black oxide of manganese formerly called glass soap?

Because it cleanses certain impurities, and especially the green tinge which is apt to arise from impure alkali.

Why do glass-cutters use the point of a diamond for dividing and shaping their panes?

Because diamond is the hardest of known substances, and cuts or scratches every other body.—*Arnott.*

Glass can, however, only be cut by the *natural* point of the diamond. There are various other methods of cutting glass, among which the following, from a French Journal, merits notice.

If a tube, or goblet, or other round glass body is to be cut, a line is to be marked with a gun-flint, having a sharp angle, an agate, a diamond, or a file, exactly on the place where it is to be cut. A long thread, covered with sulphur, is then to be passed two or three times about the circular line, and is to be inflamed and burnt; when the glass is well heated, some drops of cold water are to be thrown on to it, when the pieces will separate in an exact manner as if cut with scissors. It is by this means that glasses are cut circular into thin bands, which may either be separated from, or repose upon, each other at pleasure, in the manner of a spring.

Why is the white enamel in imitative gold trinkets of such little value?

Because it is merely glass rendered more or less milky or opaque, by the addition of oxide of tin; it forms the basis of many of the coloured enamels, which are tinged with the metallic oxides.

Why are leaden bullets let fall on glass cooled in the open air, without breaking it, whereas a few grains of sand also let fall on the glass would break it into a thousand pieces?

Because the lead does not scratch the surface of the glass; while the sand, being sharp and angular, scratches it sufficiently to break it.

Why are glass-house cinders, or clinkers, employed in hydraulic mortar?

Because they contribute to its rapid consolidation. This advantage was employed in the construction of the bridge of Louis XVI. at Paris, and in building the jetties and fort at Cherbourg.

POTTERY.

Why is common clay of a brownish colour?

Because of the oxide of iron which it contains.

Why is nickel prized by the French manufacturers of porcelain?

Because its oxide affords them a very delicate grassgreen, and like other metallic colours this bears the intense heat of their ovens without injury. A hyacinthine colour may be given to flint-glass by melting it with this oxide.—*Parkes.*

Why is manganese serviceable in the arts?

Because its oxides are used in preparing bleaching liquor; in purifying glass, (for which purpose, according to Pliny, it was employed two thousand years ago); in glazing black earthenware; and colouring porcelain enamels.

Why are the Staffordshire potteries concluded to be of Roman origin?

Because evident remains of Roman potteries have been repeatedly discovered, at a considerable depth below the present surface of the land.

The better kinds of pottery, called in this country, *Staffordshire waré*, are made of an artificial mixture of alumina and silica; the former obtained in the form of a fine clay from Devonshire chiefly; and the latter consisting of chert or flint, which is heated red hot, quenched in water, and then sifted to powder. Each material, carefully powdered and sifted, is diffused through water, mixed by measure, and brought to a due consistency by evaporation: it is then highly plastic, and formed upon the potters' wheel or lathe into various circular vessels, or moulded into other forms, which, after having been dried in a warm room, are enclosed in baked clay cases, resembling bandboxes, and called *seggars;* these are ranged in the kiln, so as nearly to fill it, leaving only space enough for the fuel; here the ware is kept red hot for a considerable time, and thus brought to the state of *biscuit.* This is afterwards *glazed*, which is done by dipping the biscuit-ware into a tub containing a mixture of about 60 parts of litharge, 10 of clay, and 20 of ground flint, diffused in water to a creamy consistence and when taken out enough adheres to the piece n give an uniform glazing when again heated. The pieces are then again packed up in the seggars, with small bits of pottery interposed between each, and fixed in a kiln as before. The glazing mixture fuses at a very moderate heat, and gives an uniform glossy coating, which finishes the process, when it is intended for common white ware.

The manufacture of Worcester porcelain is described as follows: The siliceous and other substances are first pulverized by an iron roller, which weighs upwards of two tons, and revolves in a groove not unlike that of a cider-mill; after this they are calcined, and then ground at the water-mill, sufficiently fine to filter through sieves, through which no particle of greater dimensions than the 57,000th part of an inch can pass. The composition then, in its liquid state, is dried upon the slip kilns till it becomes of the consistency of clay, when it is taken to the throwing-room, where the ware is first formed; and from thence to the store-room, in which it is placed to dry gradually, thus preparing it for turning and pressing. The articles being applied to the latter are diminished in thickness about one half: the ware is then put into the first set of kilns, called Biscuit Kilns, in which it is burned nearly sixty hours. Having passed through these kilns, such pieces as have been warped by too great heat, are reburned in the second. After this the articles are prepared for receiving their glazing, which accomplished, they are a third time committed to the fire,—and when the glaze is sufficiently vitrified, they are taken out, and when cool, receive their finest embellishment in the painting-room; they are then, a fourth time, condemned to the furnace, for the purpose of incorporating the gilding and the colours with the glaze, after which they are burnished for the market.

Why are the patterns upon ordinary porcelain chiefly in blue?

Because of the facility of applying cobalt. These patterns are generally printed off upon paper, which is applied to the plate or other article while in the state of biscuit, and adheres to the surface when heat is properly applied.

Why are gum-water and borax used in gilding porcelain?

Because, upon the application of heat, the gum burns off, and the borax vitrifying upon the surface causes the gold firmly to adhere; it is afterwards burnished.

Why ought the materials for porcelain to be selected with the greatest caution?

Because it is necessary that the compound should remain perfectly white after exposure to heat; that it should endure a very high temperature without fusing, and at the same time acquire a semi-vitreous texture and a peculiar degree of translucency and toughness. These qualities are united in some of the oriental porcelain, or *China*, and in some of the old Dresden, but they are rarely found co-existent in that of modern European manufacture. Sèvres and Worcester porcelain is extremely white and translucent, but it is more apt to crack by sudden changes of temperature, more brittle, and, consequently, requires to be formed into thicker and heavier vessels; and more fusible than the finest porcelains of Japan and China. Painting on porcelain or in enamel is an art of great difficulty, and with every care there are frequent failures: hence the costliness of fine porcelain.

The Sèvres porcelain manufactory is in a village of that name about two leagues from Paris. It was purchased by Louis XV. in 1759, and has since been the property of the French Government. Here was made a complete service for Louis XVI. of which each plate cost 25*l.* and in the Tuilleries is a Sèvres vase which cost 1000*l.* In 1801, Brogniart, the distinguished geologist, was appointed director, and to his exertions the establishment is principally indebted for its celebrity since the Revolution.

According to Professor Silliman, the porcelain of America bids fair to rival that of the old world. Speaking of a manufactory in Philadelphia, he says: "the porcelain is very beautiful in all the principal particulars: in symmetry of modelling, in purity of whiteness, in the characteristic translucence, in smoothness and lustre, and in the delicacy and richness of the gilding and enamel painting. That it rivals the finest productions of Sèvres itself, it is not necessary to assert; but it certainly gives every assurance, that if properly supported, it will not fail to meet every demand of utility and taste, which this great and growing country, may present." The raw material is very abundant near Philadelphia, and in many other parts of the United States.

Why is Wedgwood-ware so called?

Because it was the invention, or rather improvement of Mr. Wedgwood, who, for that purpose brought modellers from Italy and other parts of the Continent, and employed a competent chemist to superintend his experiments. By this means, he not only excluded the foreign manufacture from the market, but also supplied a large quantity for exportation, extending the business far beyond all former example.

LINEN, COTTON, ETC.

Why is linen believed to have been originally manufactured in Egypt?

Because of its frequent mention in the books of Moses, the most ancient of the Scriptural writers. The original Hebrew, not, however, specifying the substance of which the cloth called in the version, linen, was formed, would be only slight evidence of the manufacture of *flaxen* cloth in Egypt at that period, were it not from thence that it was first obtained, and thence only that Europe was for a long time supplied with it. Mummies are also generally found swathed in linen;

and, as the art of preserving bodies in that manner was practised in Egypt in the remotest ages, there can be no doubt that linen was made there at an æra of very great antiquity.

Why did the manufacture of linen make but little progress in Europe during the middle ages?

Because it was confined, both then and for a long period afterwards, to private families, where the thread was spun, and the web was wove for domestic use; and its scarcity as an article of apparel, has been considered as one of the chief causes of the leprosy. Linen, indeed, seems to have been earlier adopted as a luxury for the table than the person, and we read of its being used at banquets long before it was known as an article of dress.

Why is the newly invented French "papier linge" so called?

Because it consists of a paper made to resemble damask and other linen so cleverly, that it is impossible, without examination, to detect the difference; and even to the touch, the articles made from the *papier linge* are very much like linen, and are used for every purpose to which linen is applicable, with the exception, of course, of those in which strength and durability are required. The price is very low: a napkin costs only five or six centimes, (about a half-penny) and when they are dirty, they are taken back at half-price.

Why is it conjectured that fine India cottons were used in ancient Rome?

Because there was a regular commercial intercourse established through the medium of Egypt between Rome and India, the chief part of which was on the coast of Malabar, (which has been ever considered as the greatest manufacturing district of the East) where the art of weaving was practised at the remotest period of which we have any account. Mr. Gifford, in a note to his translation of *Juvenal*, tells us, that the "*sericæ* *vestes* were what we call fine cottons, imported into Europe in Juvenal's time, as they were ages before, from India, through the country of the Seres, the modern *Bochara*:" and this is strongly corroborated in the *Georgics* of Virgil, which seem evidently to allude to the cotton plant:

> Of Æthiop's hoary trees and woolly wood,
> Let others tell: and how the Seres spin
> Their fleecy forests in a slender twine.
>
> *Dryden's Translation.*

Among the Greeks and Romans, spinning was the chief employment of the women: the rites of marriage directed their attention to it; and the distaff and fleece were not only the emblems but the objects of the most important domestic duties of a wife. The machinery employed in weaving, though perhaps rude in its construction, was, in principle, similar to that still in use; and the process of fulling and preparing the cloth, seems to have resembled the modern practice in every particular point, except that of shearing the nap, with which the ancients do not appear to have been acquainted. In early records we do not, however, read of cloth being measured, which appears to have arisen from a custom of weaving no more cloth in one piece than was sufficient to form a single dress.

Muslins are to this day manufactured by the primitive loom in India, probably without alteration of the form in use during the earliest ages of its invention. It consists merely of two bamboo rollers, one for the warp, the other for the web, with a pair of geer, and the shuttle performs the office of the batton. This simple apparatus, the Indian weaver frequently erects under the shade of a tree. He digs a hole large enough to contain his legs, and the lower part of his geer; he then stretches his warp, by fastening the rollers at due distances in the turf, and suspends the ballances of the geer from the spreading branches of the tree; two loops beneath the geer, into which he inserts his great toes, serve instead of treddles; and with his long shuttle, he draws the weft, throws the warp, and afterwards closes it up to the web. The spinning is still performed by the ancient operation of the distaff. —*Beckmann.*

Why is woollen a less advantageous manufacture than cotton?

Because wool undergoes great waste in the process of being made into cloth, by scouring and shearing, which may be taken at one half, and the expense is greater, whilst cotton incurs no waste of importance. In 1819 the consumption of cotton in Great Britain was 428,500 bags; in 1822, 550,800; in 1825, 615,940; in 1827, 662,900; and in 1828, 732,700; by which it appears that the consumption was nearly doubled within ten years.

The average fineness of cotton may be taken at twenty hanks to the pound; and, as each hank is 840 yards, or nearly half a mile, every pound is nearly ten miles; and the whole, about 400,000 miles, are produced in about sixty-six working hours. In round numbers, this is 6000 miles per hour, or 100 miles a minute. Every fibre passes through no less than ten sets of machinery; hence the united spindles and threads travel through 1000 miles a minute. The noise of their united frictions and collisions, and the united hum of thousands of little spindles, each revolving 4000 miles a minute, may therefore be accounted for.

The estimated number of looms propelled by water and steam power, in the United Kingdom, is 58,000. The average produce, taking it at twenty-two square yards a day, makes 1,254,000, or 1,741 yards a minute; weekly, 7,524,000; monthly, 31,300,000; yearly, 376,200,000. Allowing six yards to each person for yearly consumption, will supply 62,700,000, and will cover 62,700 acres of ground, and in length would extend 213,750 miles, and reach across the Atlantic Ocean seventy-one times.—*Manchester Journal.*

Among the wonders of this branch of manufacture the following deserve mention. In 1745, a woman at East Dereham, in Norfolk, spun a single pound of wool into a thread of 84,000 yards in length, wanting only eighty yards of forty-eight English miles; which, at that period, was considered as a circumstance of sufficient curiosity to merit a place in the records of the Royal Society. Since that time, however, a young lady of Norwich has spun a pound of combed wool into a thread of 168,000 yards, and she actually produced from the same weight of cotton a thread of 203,000 yards, equal to upwards of 115 English miles:—this last thread, if woven, would produce about twenty yards of yard-wide muslin. Even our young readers may remember the eccentric triumph of Sir John Throgmorton, who sat down to dinner wearing a coat which had that morning been wool on the sheep's back.

Why is the spinning-frame superior to the jenny?

Because, though the *spinning-jenny* invention, in 1767, by Hargreaves, a carpenter, at Blackburn, in Lancashire, gave the means of spinning twenty or thirty threads at once, with no more labour than had been previously required to spin a single thread,—the thread spun by the jenny could not be used except as weft, being destitute of the firmness or hardness required in the longitudinal threads or warp. Mr. Arkwright supplied this deficiency by the invention of the *spinning-frame*, that wonderful piece of machinery, which spins a vast number of threads of any degree of fineness or hardness, leaving to man merely to feed the machine with cotton, and to join the threads when they happen to break. It is not difficult to understand the principle on which this machine is constructed, and the mode of its operation. It consists of two pairs of rollers, turned by means of machinery: the lower roller of each pair is furrowed or fluted longitudinally, and the upper one is covered with leather; to make them take a hold of the cotton. If there were only one pair of rollers, it is clear that a carding of cotton, passed between them, would be drawn forward by the revolution of the rollers; but it would merely undergo a certain degree of compression from their action. No sooner, however, has the carding, or *roving*, as it is technically termed, began to pass through the first pair of rollers, than it is received by the second pair, which are made to revolve with (as the case may be) three, four, or five times the velocity of the first pair. By this admirable contrivance, the roving is drawn out into a thread of the desired degree of tenuity, a twist being given to it by the adaptation of the spindle and fly of the common flax-wheel to the machinery. Such is the principle on which Mr. Arkwright constructed his famous spinning-frame. It is obvious that it is radically different from the previous methods of spinning, either by the common hand-wheel or distaff, or by the jenny, which is only a modification of the common wheel. Spinning by rollers was an entirely original idea. Mr. Arkwright stated that he accidentally derived the first hint of his great invention from seeing a red-hot iron bar elongated by being made to pass between rollers; and though there is no mechanical analogy between that operation and the process of spinning, it is not difficult to imagine that by reflecting upon it, and placing the subject in different points of view, it might lead him to his invention.*—*Ency. Brit.*

Why is the spinning mule so named?

Because it is a compound of the machinery used in the hand-jenny and water-frame.

Why is cambric so called?

Because it was first manufactured at Cambray in France.

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* Mr. Arkwright's machines, on their first introduction, were reckoned adverse to the interests of the working-classes, and repeated attacks were made on the factories built for them; yet the result has shown the absurdity of these prejudices. It is doubtful whether 30,000 persons were employed in all the branches of the cotton manufacture at the above period; whereas, in consequence of those very inventions which the workmen endeavoured to destroy, there are now upwards of 1,000,000 directly engaged in its different departments.

Why may Rouen be considered the Manchester of France?

Because it is the great seat of the cotton manufactures, containing nearly 200 factories, employing from 55 to 60,000 persons. The proximity of Rouen to Havre-de-grace, the great American port, gives it the same advantage, in point of situation, as Manchester derives from being near Liverpool.

Why does netting differ from knitting?

Because the first is performed by knotting into meshes that cannot be unravelled; while the second is, by a certain arrangement of loops so connected with each other as to be highly elastic without separation, yet capable of being unravelled, and having the same thread applied to any other use.

Why has it been conjectured that knit-stockings were invented in Scotland?

Because the earliest account of this kind of knitting is traced in a patent granted in France to a guild of knitters, who chose St. Fiacre, a *Scotchman*, for their patron.

The introduction of knitting into this country, is however, involved in much controversy. Howell says that "Henry VIII. wore, ordinarily, cloth hose, except there came from Spain, by great chance, a pair of silk stockings. King Edward, his son, was presented with a pair of long Spanish silk stockings, by Thomas Gresham, his merchant." But, that woollen stockings were not only in use, but perhaps knit in this country, during the reign of Henry VIII. seems placed beyond doubt by this authentic household record:—

"1533. 25 H. 8. 7 Sept.—Peyd for 4 peyr of knytt-hose, viii *s*.
"1538. 30 H. 8. 3 Oct.—Two peyr of knytt-hose, i *s*."

The invention of the stocking-loom is thus recorded in the inscription to an old painting of one in the Stocking Weavers' Hall, London:—"In the year 1589, the ingenious William Lee, Master of Arts of St. John's College, Cambridge, devised this profitable art for stockings, (but being despised, went to France,) yet of iron to himself, but to us and others of gold: in memory of whom this is here painted."—Seven of Lee's workmen returned to England, and with another laid the foundation of the stocking manufactory in this country, where, in 1663, the masters were incorporated by letters-patent. In their petition the machine is described as consisting of two thousand parts, and making, almost instantaneously, two hundred meshes.

The formation of the *Society of the Stocking* at Venice, in 1590, implies its antiquity on the continent.*

Why are Angola hose preferred for their superior warmth?

Because they combine worsted and cotton in the closest intermixture of the fibre. The separate materials are first passed through a machine called a picker and blower, to clean and lighten the wool or cotton, so that half an ounce will fill a bushel measure. These are then carded together, by which the intermixture is effected, part of each material being dyed blue and black. It is then spun of various fineness by throstles and mules.

Why does the knitting of thread-lace differ from that of stockings?

Because, in making stockings, only one thread is employed, and that in one uniform way; whereas, lace is formed of as many threads as the pattern and breadth require.

Why does lace exhibit various patterns?

Because the pattern is drawn on a piece of parchment, and fastened to the cushion of a circular box with pins formed on purpose, which are stuck through it in various places, according to the design intended to be represented; the requisite number of threads are then wound upon a small bobbin, one end being tied to each pin, and these are thrown over and under each other in various ways; so that the threads twine round the pins, and thus form the multiplicity of holes or eyes which produce the desired figure.

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* See Part III. ORIGINS and ANTIQUITIES, p. 57.

Why is some knit-lace called point?

Because it has been worked, or embroidered, with the needle: when formed of silk, it is called *blonde.*

Why was cotton-lace formerly in such disrepute?

Because the quality of lace depends on its transparency, and at first, the meshes of cotton were encumbered with loose fibres, which destroyed its clearness; and to remove these, for some years appeared to be an insuperable difficulty.

Why is lace "gassed?"

Because the flame of the gas may penetrate the meshes, and free them of these loose fibres, which is done without the smallest injury to the fabric. The apparatus of Mr. Hall, of Nottingham, for the purpose of *gassing* lace, is thus described:—He exposes the lace to a horizontal tube, provided with a series of orifices, through which ascends carburetted hydrogen gas, which, lighted at one end, takes fire through the entire lengths of the tube, making a delicate blue flame, about half-an-inch high. This is supported by the oxygen of the atmosphere; but the oxygen is drawn to the flame by a cap, the whole length of the horizontal tube; and the cap is exhausted by its connexion with an air-pump, of extraordinary dimensions, worked by machinery: hence a brisk current of air constantly passes over the inflamed hydrogen. At the same time, stop-cocks and valves are so provided, as to regulate both the emission of the hydrogen gas, and the exhaustion of the gas above it. A similar tube, with orifices, and a cap, is laid at about a foot distance from the other, and then by means of rollers on each side, the lace is carried through the two lines of flame, and being returned again, the operation is complete. The several machines, as well as the exhausting pumps, are worked by water power.—*Sir R. Phillips's Tour*

Why does ordinary weaving differ from lace-weaving?

Because it has the warp perpendicular instead of horizontal; and, instead of the shuttle moving at right angles, brass bobbins, in brass carriages of very curious and delicate structure, are made to pass in cross directions round the warp threads obliquely, so as to produce the hexagonal meshes. In truth, the principle of the machine is to produce the very same result as is effected by the evolutions of the bobbins on the pillow or cushion in hand lace-making.

Weavers, or lace-machine hands, are paid by the number of holes, or meshes, which run from 320 to 520 the square inch. The estimate is made by the rack, or 240 holes lengthways, for which they receive, according to breadth, from threepence to eightpence per rack.

WOOLLENS.

Why was Spanish wool formerly so valuable?

Because it was the produce of the original stock, from which the whole of the Merino sheep now in existence have been drawn. This was from a flock transported from the Coteswold Hills in Gloucestershire, to Castile, in 1464. Until within these few years, the only fine wool known was the Spanish wool, which, at that time, was supplied to England, France, and the Netherlands, for their fine cloth manufactures. But the ravages of war destroyed many flocks, and the original system of keeping the sheep was lost, so that the wool has degenerated into a quality not worth more than one-third of the same stock of sheep in Germany.

Why has Saxony become so celebrated for its wool-trade?

Because the late King of Saxony, when Elector, introduced the breed of Merino sheep into Germany, which has since transferred the valuable trade in fine wool, almost wholly from the Spanish to the German soil. Thus, Germany realized in 1829, the sum of

£5,199,934. by the growth of wool, instead of the worthless hair produced upon the old indigenous sheep of the country, which was scarcely in sufficient quantity to supply the peasantry with worsted petticoats and stockings. Of the above quantity, there were imported into England, 23,110,822 lb. of wool, which averaged at 1*s.* 6*d.* per pound, makes a return of £1,733,311. 13*s.* There is likewise a growing prospect of a supply of Merino wool, equal to the consumption of Great Britain, being produced from her two colonies of New South Wales and Van Dieman's Land.

Why is foreign superior to British wool?

Because abroad the wool is grown without seeking any other result than wool,—whereas, in England, the farmer sacrifices every advantage of quality in the wool, to the necessity of exposing the sheep to inclement weather on the fallow land; and to the production of a fine fat carcass—both of which are incompatible with anything like excellence in the quality of the wool. If these motives did not exist, the sheep would then be kept *for their wool;* but under so very different a mode of treatment, as to place it on a level with the Merino wool of Germany.

English historians generally attribute the establishment of the woollen manufactures in this country to the reign of Edward III., but according to the Exchequer records, there were several guild fraternities of weavers established here so early as the middle of the twelfth century. Beyond this, Gervase of Canterbury, who wrote about the year 1202, says, when speaking of the inhabitants of Britain, that "the art of weaving seems to be a peculiar gift bestowed upon them by nature."

Why is it inferred that the finest wool might be grown in England?

Because in this country every circumstance attending the breed and mode of keeping sheep, is favourable to a most extensive growth of wool; as exposure to the changes of the atmosphere, and the extreme richness of their food, both tend to increase the weight of covering on the animals. The average weight of a fleece of the German Merino breed, is somewhere about 2½ to 3 pounds; whilst that of a fat Leicester sheep is from 8 to 9 pounds.

In Russia, an instrument called a wool-measure, has lately been invented, by aid of which, the breeders of sheep who desire to improve their stock, may choose, by the fineness of their wool, the best rams to breed from: they may even ascertain the different degrees of the fineness of the wool, in different parts of the body of an animal, or if a single hair be of the same diameter throughout its whole length; the measure being divided into one-hundred-thousandth part of an inch.

Why does the prosperity of the wool-trade in France, depend on the exertions of the agriculturists to ameliorate the quality of the fleeces?

Because the French government encourage the exclusive use of their own wool, by heavy duties on the raw material of other countries; and, accordingly, nearly four-fifths of the wool consumed in France is of native produce.

Why was the woollen manufacture of France so prosperous under Louis the Fourteenth?

Because Colbert, the famous minister of that day, persuaded the king to offer a bonus of 2,000 *livres* for each loom at work, and to permit the nobility to enter into manufacturing speculations without derogating from their rank.

Why does each country of the earth produce its own peculiar wool or cloth?

Because every one has some breed of sheep or other, either indigenous to the climate, or naturalized by the inhabitants from some other part. Of these there is an endless variety, each producing a different quality of wool, from the extraordinarily fine Merino wool, grown in Silesia, down to the coarse, harsh, and brittle clothing of the sheep in tropical climates.

Why have the Gobelin manufactories become so celebrated?

Because they were originally established by Jean Gobelin, upon the river Bièvre, near Paris, the water of which is considered very favourable to the process of dyeing. The family of Gobelin were, however, only dyers, although their name became attached to the quarter in which they lived, and even to the above river. They soon became rich, renounced their trade, and filled various offices in the public service.

Why were the Gobelin tapestries so named?

Because the successors of the Gobelins not only dyed wool, but made tapestries. Formerly works of this kind were confined to Flanders, where the celebrated tapestry after Raphael's Cartoons was executed; but, at present, there is no manufactory equal to that of the Gobelins.

Why are the carpets of the Gobelins and the Savonnerie so highly prized?

Because of the length of time required to perfect them; sometimes five or six years. They are seldom valued at less than £200 or £300 each. The largest carpet ever made at *la Savonnerie*, is probably that manufactured for the gallery of the Louvre. It consists of seventy-two pieces, and is more than 1,300 feet in length.

In carpet weaving, the wool passes through seventeen processes or sets of hands, to produce the warp. Thus, the fleece wool is sorted; then scoured; and combed by machine or hand. It is then run through a breaking frame and carding-engine; thence it is carried to various drawing frames, to produce regularity in the combined fibres; it is then made into a roving, and carried to the spinning-frame and made into single-worsted; afterwards double; and then ready for scouring and dyeing, warping and weaving.

Why are Cashmire shawls so successfully manufactured in France?

Because the breed of the Thibet goats has been naturalized there; and the French wool supplies the place of the oriental so perfectly, that all smuggling from India is at an end.

It is said that these shawls were brought into use by the officers of the army of Egypt after their return from the expedition so fatal to the Mamelukes, from whom a large quantity was captured. The rage then began among the French ladies for these beautiful articles, but their very high prices, as well as that of the wool of which they are made, prevented them for some time from being common. The raw material is supplied by the goats which browse on the plains of Khirgiz, whence it is brought to Moscow for sale, and it is calculated that a pound of this genuine wool, which hardly suffices for the chain of a shawl, cannot be imported thence into France, washed, picked, and spun, for less than 150 francs, 6*l.* 5*s.*

Why is bombazeen so called?

Because of its corruption from *bombycina*, the Latin name for stuffs composed of a mixture of silk and woollen; and this term is from *bombyx*, silkworm, and *Sinæ*, China.

SILK.

Why was silk so little used among the Romans?

Because the Roman authors were altogether ignorant of its origin; some supposing it to be grown on trees, as hair grows on animals, others that it was produced by a small fish, similar to the mussel, which is known to throw out threads for the purpose of attaching itself to rocks; others that it was the entrails of a sort of spider, which was fed for four years with paste, and then with the leaves of the green willow, till it burst with fat; and others that it was the produce of a worm which built nests of clay and collected wax.

Why is it said that we are indebted to the bigotry of former times for our present improved silk manufactures?

Because, in the year 1686, nearly 50,000 manufacturers fled from France, took refuge in England, in consequence of the revocation of the Edict of Nantz, by Louis XIV. who thus, as Pennant observes, sent thousands of the most industrious of his subjects into this country, to present his bitterest enemies with the arts and manufactures of his kingdom: hence the origin of the *silk trade* in Spitalfields. It appears, however, that there was a company of silk women in England so early as the year 1455; but these were probably employed in needleworks of silk and thread. Italy supplied England and all other parts with the broad manufactories till 1489. In 1620 the broad manufacture was introduced into this country; and in 1686 the company of silk-throwsters employed above 40,000 persons.

As a specimen of individual enterprise in this branch of manufacture, we must notice Sir Thomas Lombe, who, about the year 1724, erected in an island on the Derwent, near Derby, a curious mill for the manufacture of silk, the model of which he had brought from Italy, at the hazard of his life. This machine was deemed so important, that, at the expiration of Sir Thomas's patent, parliament voted him 14,000*l.* for the risk he had incurred, and the expense attending the completion of the machinery. This contained 26,586 wheels; one water wheel moved the whole, and in a day and night it worked 318,504,960 yards of organized silk. Such, however, is the march of ingenuity, that Sir Thomas's famous machinery has not been used at Derby for some years, but improved machinery, which performs twice the work, in less room, is now adopted.

Why is silk one of the most important of manufactures?

Because it furnishes subsistence to several million of human beings; since there is scarcely an individua in the civilized world who has not some article of silk in his possession.

The perseverance of our manufactures has enabled them to ship British Bandana handkerchiefs for India, a circumstance which was triumphantly mentioned by the late Mr. Huskisson, in the House of Commons, about two years since. They have also been exported to France, in considerable quantities.

In the printing of silk handkerchiefs there has been considerable improvement during the last few years. Most of the India handkerchiefs are now printed in England. Some of the blocks display first-rate ingenuity; the patterns or subjects having all the attractions of engraved prints. Thus, it will be curious, a few years hence, to see the wonders of our times, as the Thames Tunnel, &c. and the political characters of the present day, treasured up in the cabinets of the curious, on pocket-handkerchiefs. Yet the idea is only a refinement of the old plan of printing the alphabet, and cuts of nursery stories, on cotton handkerchiefs, for children; the silk prints being but for "children of a larger growth." We believe the public are indebted for these amusing embellishment to the ingenious Mr. Applegath, of Crayford, Kent, whose patent improvements in block-printing, generally, deserve more space than we can here devote to them.

END OF PART X.